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Millivac

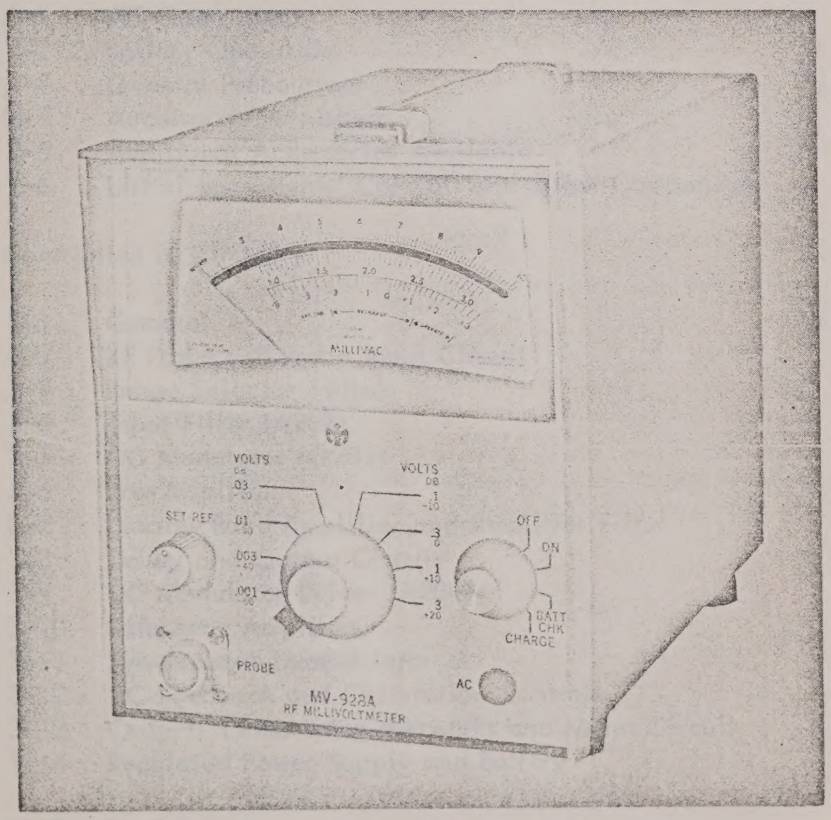
MV-928A

NE
4888

OPERATING AND SERVICING MANUAL

MODEL MV-928A

RF MILLIVOLTMETER



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SPECIFICATIONS

FREQUENCY RESPONSE & ACCURACY.....	100KC to 100MC ± 3% 50KC to 100KC and 100MC to 400MC ± 5% 10KC to 50KC and 400MC to 1.2GC ± 10% (Useful up to 2.5GC)
SCALE DISTRIBUTION.....	Expanded linear scale on all ranges.
TOTAL RANGES.....	8, 1mV to 3V full scale in 10db steps, readability 200uV.
WARM-UP TIME.....	None.
DB SCALE.....	0-dbm is equivalent to 1mW into 50 Ω
INPUT IMPEDANCE: (Typical Values).....	Approx. 3pF and 100K ohm. Both components are a function of RF frequency and level. (See Fig. 2-1).
RESPONSE.....	RMS up to 30mV; peak above 30mV; calibrated in equivalent terms of RMS sine wave. RMS up to 3V with 100:1 divider.
AMPLIFIER OUTPUT: (across 2K).....	1.0V DC, 500 μ A @ full scale.
ACCESSORIES FURNISHED.....	Probe with cable, high impedance tip, BNC 50 Ω termination adapter and output plug.
OTHER ACCESSORIES AVAILABLE.....	100:1 capacitive voltage divider; BNC, N, or GR terminations; and Type N "Tee" Bridging adapter.
POWER LINE REQUIREMENTS.....	10 watts max. @ 117V/230V AC, 50-1000 cps. Also, Battery operated with built-in rechargeable Nickel Cadmium batteries. Minimum 8 hours of continuous operation on overnight charge.
PHYSICAL CHARACTERISTICS.....	All aluminum, lightweight construction, Tautband 6" mirror-scale indicating meter. 8-3/4" high, 6-3/4" wide, 11-1/2" deep. Weight: 14 lbs.

SECTION 1

GENERAL DESCRIPTION

1-1 FUNCTION OF THE INSTRUMENT

The MV-928A, RF Millivoltmeter offers a high order of stability through its entire range, from μV to 3V (300V with 100:1 capacitive divider). Solid state circuitry, combined with a DC driven 94 cps electro-mechanical chopper, insures very low noise performance. A built-in, rechargeable, nickel-cadmium battery is furnished, providing a minimum of 8 hours continuous operation with an overnight charge. A simplified power switch features only one "ON" position.

Additional features of the instrument are:

1. No warm-up time or heat rise due to solid state circuitry.
2. Operates at either 115V or 230V; 50 to 1000 cps.
3. Temperature-compensated probe.
4. 6" linear expanded, mirror-scale meter movement with taut-band suspension.
5. When the instrument is line operated, the battery is simultaneously recharged. The instrument will function properly even while recharging a discharged battery.
6. 10KC - 1.2GC frequency response with usable indication to beyond 2.5GC.
7. Battery condition indicator.
8. Lightweight and compact, weighing approximately 14 lbs. with battery. Size: 8-3/4" H x 6-3/4" W x 11-1/2" D

1-2 ELECTRICAL CHARACTERISTICS

The MV-928A probe employs two special, low-capacity, high-stability, germanium diodes in a full-wave configuration for RF detection. The measuring capability of the instrument is from 200 μ V to 3V in 8 ranges. It covers RF voltages reaching from the square-law region, (200 uV to 300mV) to the region of linear rectification (1V to 3V). In the square-law region the instrument is RMS responding, while in the linear region it is peak-responding. In the 30mV to 1V "transition" region, the diode characteristics gradually change from RMS to peak. This non-linear characteristic is true of all diode rectifiers, regardless of design and manufacture. Fortunately, in most applications, because of flywheel effect and harmonic filtering of tank circuits, the RF signals, at least at the oscillator circuit, will be found to be essentially sinusoidal. The instrument is calibrated in terms of RMS on all 8 ranges. However, it must be realized that some error will be introduced if the RF waveshape is other than sinusoidal above the 30mV level. If RMS measurements of

non-sinusoidal signals are desired at levels in excess of 30mV, the use of the Millivac 100:1 capacitive divider is recommended. For example, this device will divide a 3V RF signal to 30mV, allowing the probe's diodes to operate in the RMS region. There are, however, some measurements, such as two-tone test set-ups for the adjustment and measurement of linear RF amplifiers in SSB service, that require the use of an RMS calibrated, peak-reading RF voltmeter. Therefore, only for certain applications, depending upon the RF level involved, may it be advantageous to use the capacitive divider.

Semi-conductor diodes have several other characteristics that the user of the MV-928A should be aware of:

A. The capacity of the diodes varies inversely with signal level. Probe input capacity varies from approximately 3pf at 3V to 4pf at 1mV.

B. The shunt resistance of the diodes varies inversely with both signal level and frequency. For details, refer to Fig. 2-1 on page 7.

C. The shunt resistance and capacity of the 100:1 divider is also a function of both frequency and level. For details, refer to Fig. 2-1 on page 7.

SECTION 2

OPERATING INSTRUCTIONS

2-1 AC OPERATION

After unpacking the instrument and probe, make sure no concealed damage has been incurred during transit. Check that the Line Voltage slide switch on the rear of the instrument agrees with the local line voltage. If necessary, it can be changed with the aid of a screwdriver. Insert the 3-wire power cable into the polarized power socket, located at the rear of the instrument.

Connect the type G-RF probe to the instrument, lining up the key-way in the probe socket with its mating plug. A clock-wise rotation of the plug's collar will lock the connector assembly together. The instrument is energized by turning the 4-position power switch to ON and with AC present the AC pilot lamp will light. If the instrument is operated without the probe connected to it, unless the range switch is set at the 3V position, the instrument's indicating meter may drift off scale. Allowing the indicator to drift off scale however, will not harm the instrument in any way.

Having attached the appropriate probe accessory (BNC termination, high impedance tip, etc.,) select the desired range for measurement, or if the voltage to be measured is unknown, start with the highest range (3V) and work down until a reading is obtained. It will be noted that the "Set Ref" control is used only on the 1mV through 100mV ranges and has no effect on the higher ranges. It should be used to adjust the meter pointer to the "Set Ref" mark under zero-input signal conditions. This should be done preferably on the lowest range of the instrument, with the input to the probe either terminated or shorted. No re-adjustment should be necessary when switching the instrument to its higher ranges. At the low-end of the 3 to 10 scale a 200 μV point is provided. This is designated by a small 2. It should be used only on the 1mV range.

The MV-928A will operate on any power line frequency from 50 to 1000 cps. The 94 cps carrier frequency has been chosen for minimum interference from the power line frequency. The instrument employs a plug-in Input Filter (A202) providing a minimum of 50 db attenuation to the power line frequency indicated on its case. Instruments are shipped, unless otherwise notified, with the correct filter for use at the specified point of destination. However, the MV-928A can be successfully operated with an input filter having a frequency other than that of the local power line. If there is excessive meter pointer flicker or poor sensitivity, the correct input filter should be installed to reject the predominant hum signal.

2-2 BATTERY OPERATION

The instrument can be battery operated, assuming the battery is charged, by following the instructions for AC line operation in paragraph 2-1. The power cord is not connected and the AC lamp will not light. The battery condition can be monitored by setting the power switch to BAT. CHK and reading the English scale on the meter. As long as it indicates in the OPERATE region, the instrument will perform properly.

As soon as the indication falls below the lower limit of the OPERATE region into the recharge zone, it is recommended that the instrument be turned off and recharged

before operating again. Continued operation of the instrument in the Recharge area can result in reverse charging of one or more of the cells. Cells subjected to repeated reverse charging will incur accumulative damage resulting in their ultimate failure.

When the instrument is line operated and the power switch is in the ON, BAT. CHK or CHARGE position, charging current is applied to the battery. After an 8-hour continuous operating period, the charging period will take 14 hours. If the battery is excessively discharged, a longer charging period may be required.

The charging circuit operates at a maximum voltage level of approximately 14.4 volts and a ballast lamp located on the rear of the instrument limits the charging current. Whenever the instrument is line operated, charging current is applied to the battery, providing battery charging at all times. Overcharging is avoided by electronically regulating the supply at 14.4V. If it is desired to charge the battery without operating the instrument, the power switch is set to CHARGE. In this position, only the battery is charged. With the power switch set to BAT. CHK and while charging, a rough check of the battery condition can be observed. When the meter indicates full scale, the battery is approaching the end of its charge cycle. It does not however, necessarily indicate a fully charged battery. The upper limit of the OPERATE Area corresponds to approximately 14 volts, while the lower limit indicates about 11 volts.

2-3 GENERAL PRECAUTIONS

There are certain precautions that should be observed, in addition to those already mentioned in the preceding paragraphs.

A. Maximum Allowable Overload. Damage to the diode cartridge may result if the following input limits are exceeded.

RF - 25V, P-P
DC - 500V

For RF voltages in excess of 3V, our 100:1 capacitive divider is recommended.

Millivac's warranty does not apply to burned-out diode cartridges.

B. Power Dissipation Rating. All Millivac terminations for the Type G probe, with the exception of the open circuit adapter, feature a 5-watt dissipation rating. Do not exceed 5 watts RF when using any of the terminated adapters.

C. Mis-Termination. High frequency signal generators have terminated output transmission lines. The terminating resistance, corresponding to the characteristic impedance of the transmission line, is usually installed between the output terminals at the free end of the transmission line. Some generators may have the transmission line terminated in its characteristic impedance internally at the output connector. In this case, if the external transmission line is also terminated in 50 Ω, serious measuring errors may result. To avoid this mis-match, the user must check the generator in question to determine if the line is internally terminated. If such is the case, the resistor should be disconnected, allowing the 50 Ω termination of the MV-928A probe to become the required output matching resistance.

If it is not desirable to remove the internal terminating resistor, an open circuit adapter of the BNC, N, or GR type should be used. These adapters are available from Millivac as extra accessories.

D. Measurements by Means of the High Impedance Probe Tip. When making high impedance measurements by means of the high impedance probe tip, care must be exercised in measuring low levels because of the possibility of stray RF pick-up. The lowest level at which the probe is useful will depend upon the strength of the stray RF field. Due to the fact that the probe is a very wide-band device (10KC - 2.5GC), any RF signal present within the probe's response (AM-FM-TV broadcasting, point-to-point communication, etc.) may be detected. In addition, above 100MC, the inductance of the tip and ground lead, plus the probe's shunt capacitance, may cause resonances, creating large measuring errors. However, the probe is still useful for relative readings. Because of its shunt capacitance and resistance, the effective impedance drops appreciably above 100MC.

2-4 ACCESSORIES FURNISHED

A. Type G Probe. The MV-928A employs a probe with a replaceable diode cartridge. The cartridge contains the input coupling and output filter capacitors. Its spring-loaded construction guarantees positive contact with the various threaded accessories.

The built-in, temperature-compensating network is epoxy encapsulated and the entire probe and cable assembly is sealed, with the exception of the replaceable diode cartridge assembly. The probe should provide years of dependable service, the diode cartridge being the only part subject to electrical damage and easily replaceable. If the probe, other than the cartridge, ever needs service, it is recommended that it be returned to Millivac for replacement or repair.

Due to the various types of terminations available for the Type G probe, it is important that the user fully understand each accessory's function and its limitations. The following list explains the functions of these accessories.

B. Type BNC Termination Adapter (50 Ω normally supplied with the instrument). This is the most widely used termination with low VSWR to 600MC. It is not recommended for accurate measurements above this frequency. The termination features a 5 watt power dissipation rating. Refer to Section 2-3, General Precautions, when using the BNC termination adapter.

C. High Impedance Probe Tip. This tip, furnished with the meter, allows high impedance measurements up to 100MC. Refer to Section 2-3, General Precautions, when using the high-impedance probe tip.

D. Output Plug (tip, ring, sleeve type). The output plug furnished with the meter matches the output jack on the rear panel. Referring to the schematic, it will be noted that the jack is connected across a 2K precision resistor in series with the meter movement to ground. When the plug is inserted into the jack, this resistor is removed from the circuit. The external load then used must make up for this resistance. If replaced by a recorder or other external device with low resistance, it may be necessary to add resistance to make a total of 2K. The accuracy of the instrument depends upon this 2K resistance and it is

recommended that it be held with ± 1%. If the recorder is of the high-impedance type (500K or higher) a 2K ± 1% resistor may be placed across the tip and ring of the plug and connected directly to the recorder. The output voltage is proportionate to the scale reading and full-scale deflection equals 1.0V DC. The output voltage is positive with respect to chassis ground. The positive signal appears at the tip, with the sleeve being ground return.

2-5 ADDITIONAL ACCESSORIES AVAILABLE

A. 100:1 Capacitive Divider. When used between the probe and high-impedance tip or termination, the capacitive divider permits measurements up to 300V. It may also be used to attenuate RF levels from 30mV to 300uV, and from 3V to 30mV, making the instrument RMS reading at these levels. The capacitive divider has an input capacitance of approximately 5pf and an input resistance of approximately 100 megohms. Its frequency response is flat from 10KC to 250MC. The capacitive divider is useful to 1.2GC, exhibiting a slight rising characteristic caused by internal resonance. These values, however, are also functions of both level and frequency. For details, refer to Fig. 2-1 on page 7.

B. Type BNC Termination Adapter.* Normally supplied with a 50 Ω, 5 watt termination. It can be supplied for any termination value from 0 to infinity.

C. Type N Termination Adapter.* Normally supplied with a 50 Ω, 5 watt termination. It can be supplied for any termination value from 0 to infinity, and for frequencies up to 1.2GC.

D. GR-874 Series Termination Adapter.* Normally supplied as an open circuit adapter. It can be equipped, upon request, with any other termination value. It is useful up to 1.2GC.

* The three above mentioned adapters have a characteristic impedance of 50 Ω and use of termination values other than 50 Ω will result in an increased VSWR, particularly at higher frequencies. It will also invalidate the DBM scale readings. This fact must be considered when ordering special termination values.

E. Bridging N Tee Adapter (50 Ω). This adapter, when used in conjunction with the G probe for in-line RF measurements, provides low VSWR at high frequencies (better than 1.4.1 at 1.2GC). For accurate measurements of RF generators or for checking the accuracy of the instrument against a standard, such as the Ballantine Micropot, Model 40, it is recommended that the bridging tee be attached directly to the generator or micropot and the open end of the tee should be terminated with the Millivac Type N (50 Ω) termination adapter.

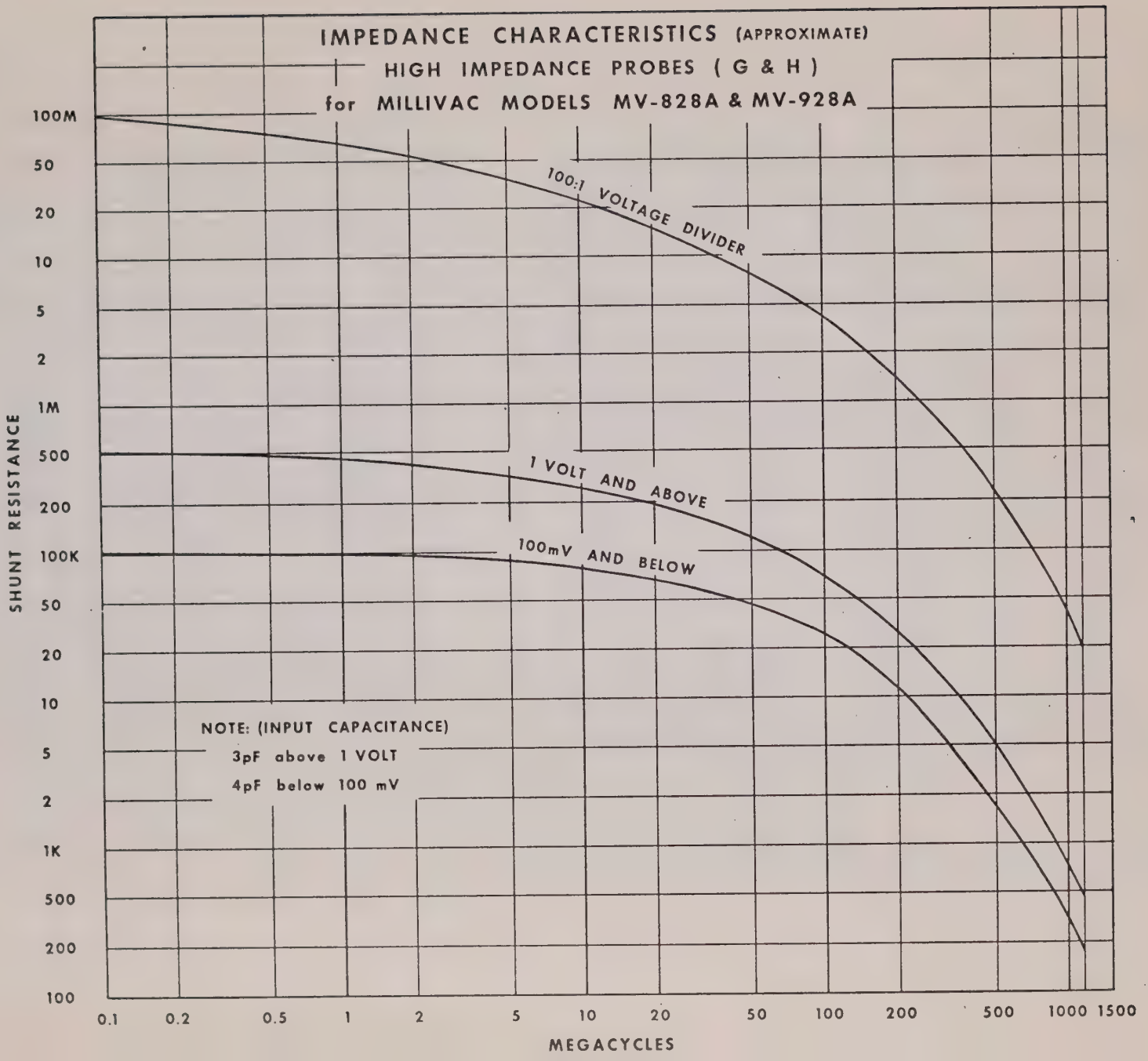

IMPEDANCE CHARACTERISTICS (APPROXIMATE)
HIGH IMPEDANCE PROBES (G & H)
for MILLIVAC MODELS MV-828A & MV-928A
100:1 VOLTAGE DIVIDER
1 VOLT AND ABOVE
100mV AND BELOW
NOTE: (INPUT CAPACITANCE)
3pF above 1 VOLT
4pF below 100 mV
SHUNT RESISTANCE
100M
50
20
10
5
2
1M
500
200
100K
50
20
10
5
2
1K
500
200
100
0.1
0.2
0.5
1
2
5
10
20
50
100
200
500
1000
1500
MEGACYCLES

Fig. 2-1

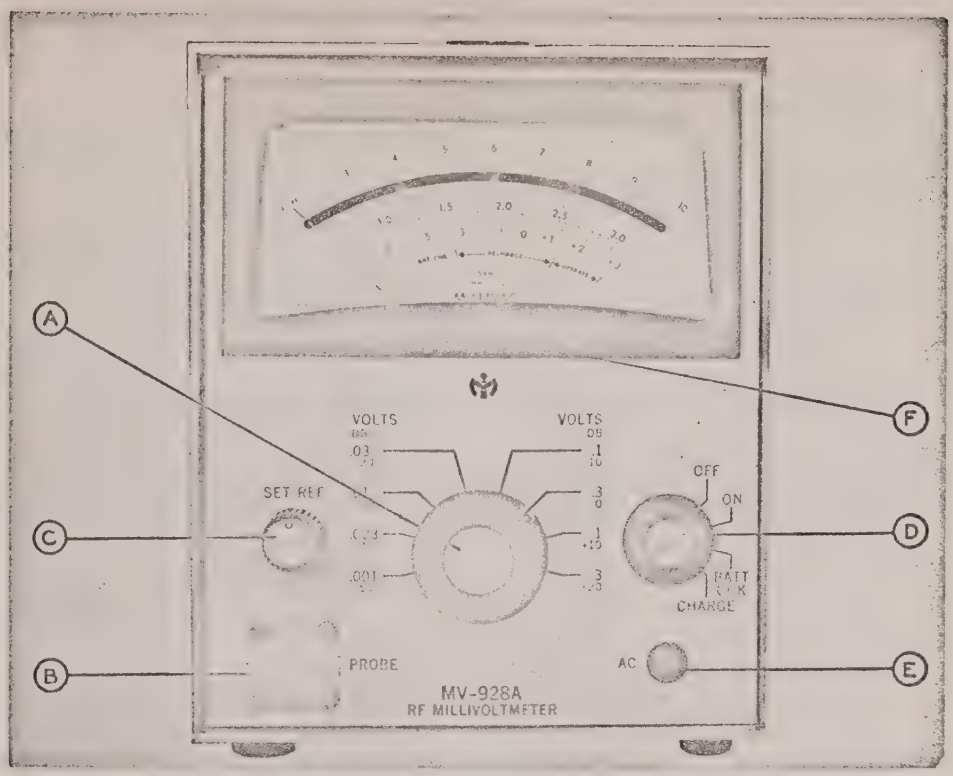


Fig. 2-1 Front View of MV-928A

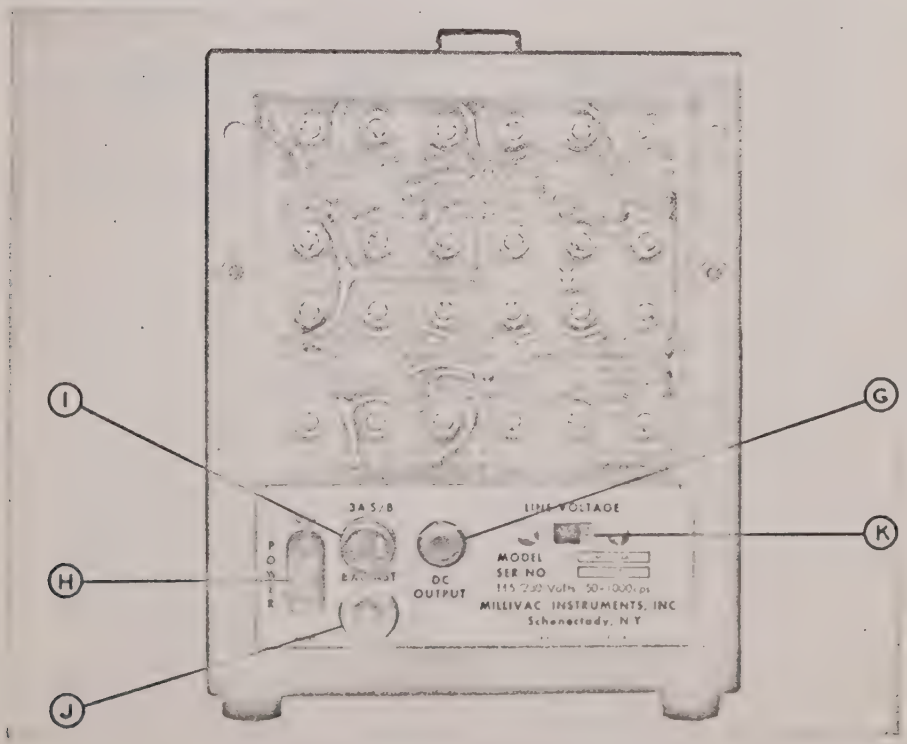


Fig. 2-2 Rear View of MV-928A

2-6 LIST OF THE INSTRUMENTS' CONTROLS AND OTHER COMPONENTS (See Fig. 2-2 and 2-3).

A. Range Selector Switch. This switch facilitates selection of any one of the eight RF voltage ranges of the instrument.

B. Probe Input Connector. A 7-pin Amphenol type connector, serves as connector for RF probe.

C. "Set Ref" Adjustment. This front-panel control is used to adjust the pointer to the reference point with zero-input signal on the lowest ranges.

D. Power Switch. A 4-position, Off, On, BAT. CHK and CHARGE switch.

E. AC Pilot Light. Permanent Neon Type, indicates whenever instrument is connected to AC line and power switch is set to ON, BAT. CHK or CHARGE positions.

F. Mechanical Zero Adjust. Provided for mechanical zero adjustment of meter movement.

G. Output Connector. This is a tip, ring, sleeve, phone-type output jack for DC output. 1.0 volt full scale is developed across a 2K load.

H. Power. Connector for the three conductor AC power cord.

I. Fuse Holder. This is a detachable bayonet type holder, containing a 0.3 amp. "Slo-Blo" fuse.

J. Ballast Lamp. Type #239 incandescent lamp used for current limiting, and battery fuse in charge circuit. Replace only with the same type.

K. Line Voltage Switch. Slide switch to allow for either 115 or 230 volt operation.

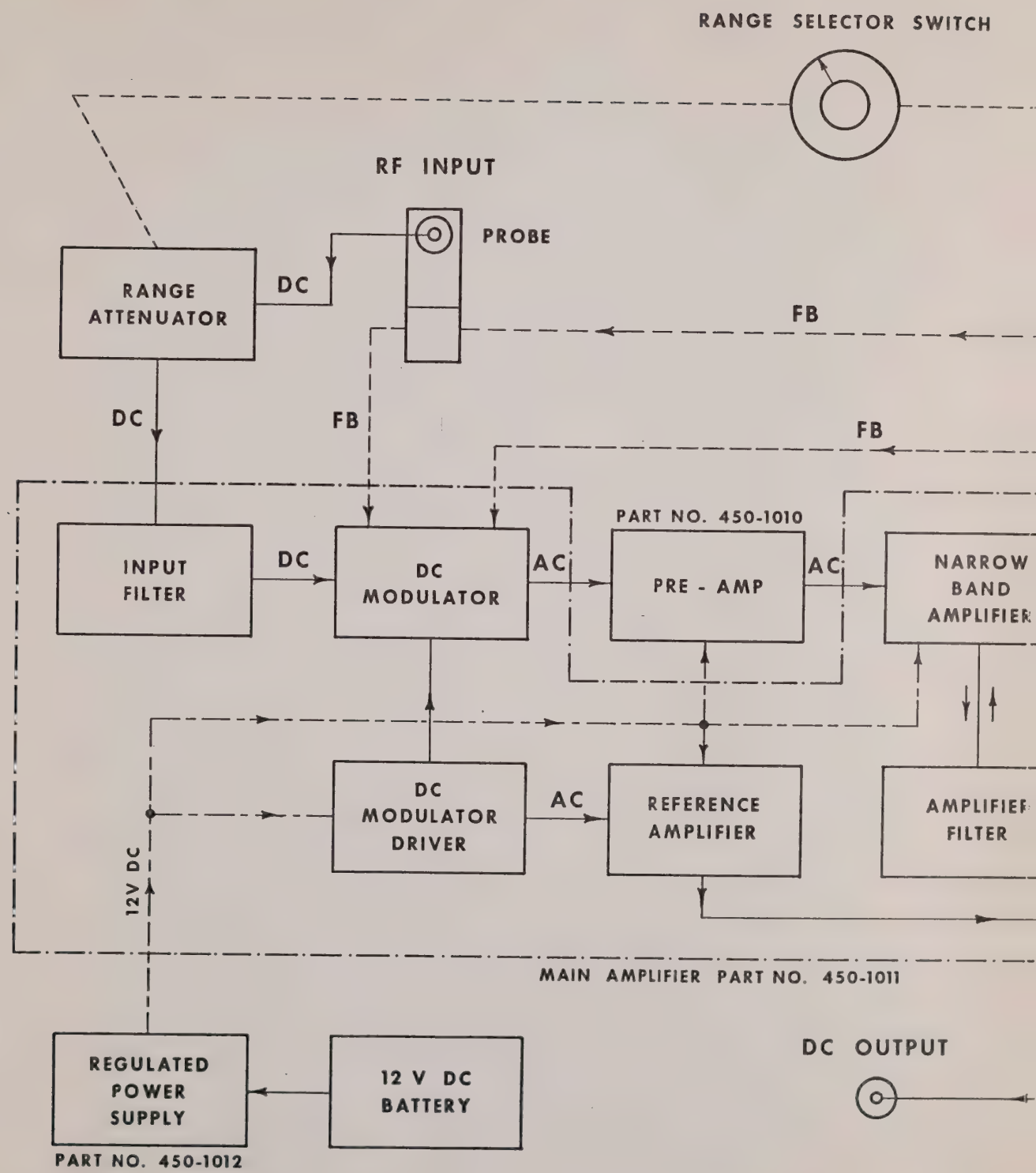
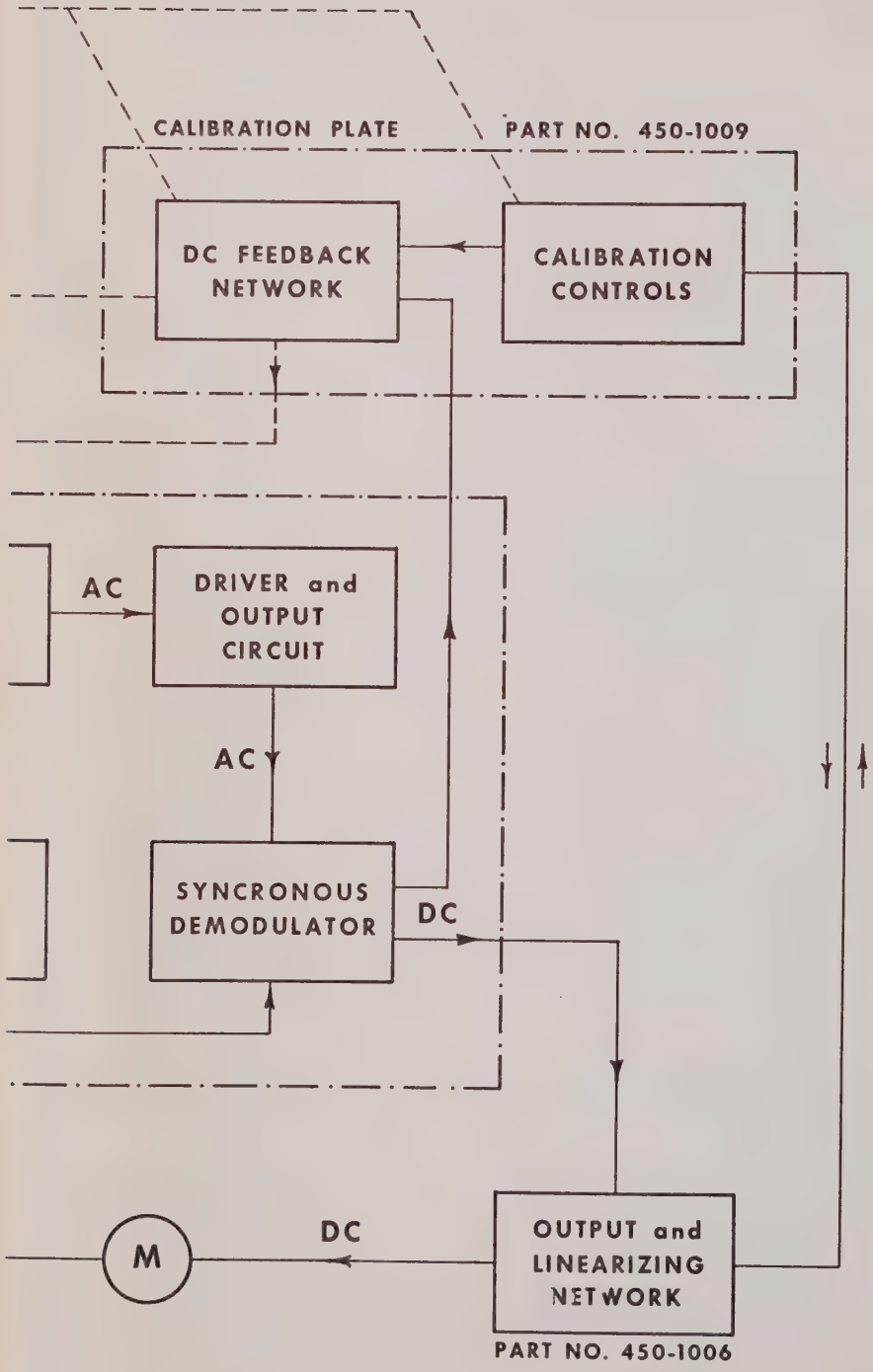


Fig. 3-1 BLOCK DIAGRAM


CALIBRATION PLATE
PART NO. 450-1009
DC FEEDBACK NETWORK
CALIBRATION CONTROLS
AC
DRIVER and OUTPUT CIRCUIT
AC
SYNCRONOUS DEMODULATOR
DC
M
DC
OUTPUT and LINEARIZING NETWORK
PART NO. 450-1006

MV-928A

SECTION 3

DESCRIPTION OF CIRCUITRY

3-1 GENERAL

The basic circuitry of this instrument is best understood by reference to the block diagram, Fig. 3-1.

The RF signal is sampled and detected by the RF probe. The probe's DC output signal after passing through the attenuator section of the range selector switch goes to the Input Filter, for rejection of power line frequency components which might cause a measuring error. A single-pole double-throw chopper (DC Modulator) converts the incoming DC signal into a nearly symmetrical square wave. The converted signal is then impedance-matched and amplified by a high impedance Pre-amplifier. The output from the Pre-amplifier stage is fed into the Narrow Band Amplifer, where its narrow band width improves the signal-to-noise ratio of the instrument. The output of this stage is further amplified in the Driver and push-pull class B Output stage. Next, the AC signal is rectified by a Synchronous Demodulator and the resultant DC output is used to provide heavy overall DC feedback, and temperature compensation. The DC output is also linearized in the Output circuit from where it is used to drive the indicating meter. The DC Modulator is driven by a 2-transistor multivibrator circuit operating from the 12 volt battery source.

The DC Modulator and its Driver determine the carrier frequency (in the order of 94 cps). The square wave output voltage of the Driver is sampled and amplified by the Reference Amplifier whose output is fed to the Synchronous Demodulator. The phase relationship between the Reference Amplifier signal and the carrier amplifier signal determine the polarity of the DC output. An electronically regulated Power Supply delivers 14.4 volts to the amplifier as well as the battery for charging purposes. A ballast lamp located on the rear of the instrument for accessability, limits the charging current to the battery.

NOTE: For the following detailed description of each circuit block, reference should be made to the complete circuit schematics for this instrument, attached at the end of this manual.

3-2 RF PROBE AND PROBE INPUT CIRCUIT

The RF probe consists of a diode cartridge assembly (replaceable only as a unit) housing a coupling capacitor, two matched diodes and a pair of filter capacitors. The sealed section of the RF probe housing contains two 10K RF filter resistors connected in series with the output terminals of the diode cartridge, and a temperature-sensing thermistor network, incorporated in the DC feedback loop of the amplifier. They are connected to the individual ranges by means of Section C and F of the range selector switch S101. The individual pins of connector J101 are by-passed to ground by capacitors C101 through C105, thus preventing any possible error introduced by stray RF pick-up in the probe cable.

3-3 RANGE SELECTOR SWITCH

The range selector switch, S101 consists of Sections A through J. Sections A

and B (Range Attenuator) contain resistive dividers supplying the full or partial voltage to the input of the amplifier, depending upon the range setting. This voltage, when chopped, amplified and demodulated, will indicate on the meter a reading corresponding to the value of the input signal (within the accuracy rating of the range being used).

Section D provides an effective SET REF control adjustment, thereby allowing restoration of the meter to its reference condition with no input signal present. This adjustment is especially necessary on the meter's lowest ranges due to the ever-present thermoelectric voltages. On the three highest ranges of the instrument (300mV, 1V and 3V), the reference control is no longer needed and is, therefore, by-passed. This reference control circuit consists of a potentiometer R119 and resistor R116.

Section E switches the Amplifier Gain Control into the emitter circuit of Q204 on the 1mV and 3mV ranges. This provides an overall gain adjustment of the AC amplifier for these ranges permitting optimum performance. This control is switched out of the circuit on the higher ranges, which results in a fixed and lower AC amplifier gain.

Sections C and F, in conjunction with Section J, form part of the DC feedback loop. Section J contains individual resistors and potentiometers to control the main feedback loop of each "Mid" range control. The thermistors, located in the RF probe, sense and correct for any thermal errors occurring as a result of the temperature characteristics of the RF diodes and are switched into the circuit through Section F.

Sections G and H switch both resistors and potentiometers for correcting the non-linearity of the RF diodes.

3-4 INPUT FILTER (A202)

This epoxy encapsulated plug-in module consists of an R/C network providing an effective AC filter with a minimum of 50 db rejection at power line frequency.

3-5 DC MODULATOR (G201)

A 94 cps printed circuit plug-in DC modulator (chopper) is employed. It chops the DC input signal and the resultant AC component is impedance matched by the input transformer T201.

3-6 PRE-AMPLIFIER (A301)

This 40 db gain Pre-amplifier features a low-noise, high impedance input achieved by the use of a high quality field effect transistor (Q301). Diodes CR301 and CR302, form a clamp circuit to protect the input transistor from excessive overload. A three-stage conventional R/C coupled, common-emitter amplifier consisting of Q302, 303 and 304 with the input transistor Q301 develops an open loop gain of approximately 60 db. A 20 db overall AC feedback loop results in an amplifier with good gain stability and transistor interchangeability. The supply voltage is held at -5.8 volts by zener diode CR305. Output limiting is achieved by CR303 and CR304, minimizing overloading of the following stages.

3-7 NARROW BAND AMPLIFIER AND AMPLIFIER FILTER

The Narrow Band Amplifier improves the signal-to-noise ratio by reducing the amplifier bandwidth. It consists of transistors Q201, 202 and 203. Q201 is a common-emitter circuit with a parallel "T" network tuned to 94 cps in a negative feedback loop from collector to base. Q202 is an emitter follower, providing impedance matching between the "T" filter and the base of Q201. Q202 also provides isolation and impedance matching to the next stage. The "T" filter exhibits high impedance at its resonant frequency rapidly decreasing at off-resonance points. With this filter in series with the negative feedback loop, a selective amplifier results with maximum output occurring at filter resonance.

3-8 DRIVER AND OUTPUT CIRCUIT

The driver (Q204) and the Class B output stage (Q205 and 206) are conventional transformer-coupled stages. Class B operation of the output stage results in low quiescent collect current and thereby minimizes battery drain. The Amplifier Gain Control, R211 is located in the driver-emitter circuit and controls the amount of degeneration developed at this stage by the position capacitor C205 on the emitter resistor. This gain adjustment is present only on the 1 and 3mV ranges. The signal developed in the output stage is applied to the Synchronous Demodulator, where rectification takes place. Before discussing this stage, an explanation of the DC Modulator Driver and Reference Amplifier is in order.

3-9 DC MODULATOR DRIVER (A204)

The Modulator Driver is an encapsulated plug-in module consisting of a two-transistor multivibrator circuit. The characteristics of the MODULATOR and DRIVER combination determine the 94 cps carrier frequency

3-10 REFERENCE AMPLIFIER

The square wave output of the DC Modulator Driver is sampled by the Reference Amplifier via transformer T204. This amplifier consisting of Q209, 210 and 211, is similar to the driver and output stage previously described and is used to develop a reference signal for the Synchronous Demodulator for correct rectification of the output signal.

3-11 SYNCHRONOUS DEMODULATOR

Q207 and 208 are utilized in this phase-sensitive rectifying circuit. The signal from the output stage (Q205 and 206) is compared with the reference signal from Q210 and Q211. The resultant DC output signal from this demodulator has a polarity corresponding to the original input signal polarity. In this type of operation, the collector current is a function of the collector voltage only and is essentially independent from other transistor parameters. The voltage applied to the base of the transistor acts only as a phase-sensitive reference.

3-12 DC FEEDBACK AND CALIBRATION CONTROLS

A portion of the DC output voltage is fed back to the chopper input circuit to provide the excellent gain stability of the MV-928A. This feedback ratio is determined by

values of a resistor and potentiometer connected in series and switched through Section J of the Range Selector Switch, S101. One of three thermistors mounted in the RF probe housing is switched in series with the previous combination by means of Section F of the Selector Switch. The DC feedback controls are marked "Mid" on the calibration plate and are used for accurate calibration of the mid-scale for each range. The appropriate feedback ratio is selected when switched to the desired range.

3-13 OUTPUT, LINEARIZING NETWORKS AND METER CIRCUIT

The DC output of the RF diode rectifiers is basically non-linear with respect to the RF input level. In order to achieve a linear output characteristic, correction networks are employed. Their function is to expand the lower end and compress the upper end of the meter scale. The networks consist of R119, 401, 402, 403, CR401 and CR402, as well as the resistors and potentiometers switched into the circuit by means of Section G and H of S101.

For better understanding of the circuitry, Fig. 3-2 shows all the details of the network involved for the 1mV range.

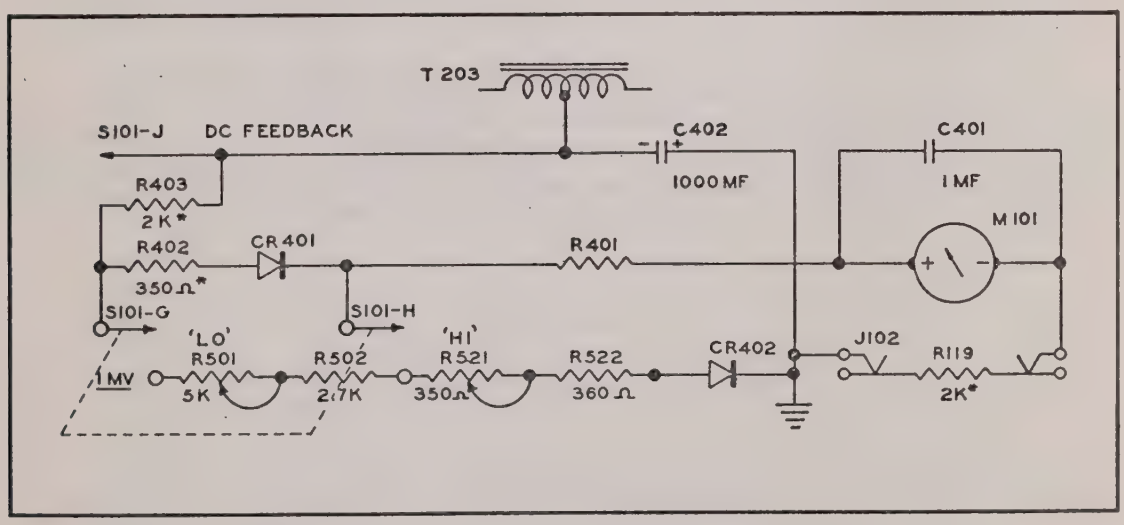


Fig. 3-2 Scale Correction Network

The rectified DC, proportional to the DC input signal, appears at the center tap of the secondary of T203 and filter capacitor C402. For low input levels, 40% of full scale and lower, the signal passes through R403, R402, CR401, R401, M101 and R119. At low levels, the resistance of CR401 is fairly high and the current through the circuit is limited. By paralleling R402 and CR401 with R501 and R502, an exact adjustment of the meter to a point corresponding with the input voltage is possible.

For higher levels, 70 through 100% of full scale, R501, R522 and CR402, paralleled with M101 and R119, provide adjustment of the meter to correspond with the incoming signal. To adjust the mid-scale point, the main DC feedback resistor (in the case of the 1mV range, R541) is utilized.

The indicating meter M101, is rated at 0-500 μ A DC.

The resistor R119, in series with M101, is connected to the circuit via J102. For external monitoring purposes, when a plug is inserted into J102, R119 is switched out of the circuit and the external monitor must provide the 2K series load. This value should be with ± 1% to maintain the rated calibration accuracy of the instrument.

3-14 REGULATED POWER SUPPLY AND BATTERY

The electronically regulated power supply includes a 115/230 volt split primary power transformer (T601). Its secondary, in conjunction with the rectifiers (CR601, CR602), is used in a full-wave, center-tapped configuration. The rectifier output is applied to the collector of the series regulator transistor Q601. The base of Q601 is biased by the temperature stable reference amplifier (Q602). The regulated output voltage appears at the emitter of Q601. An adjustable voltage divider across the output, consisting of R606, 608 and Potentiometer R607, permits adjustment of the output voltage by determining the bias of the transistor portion of Q602.

CR101 prevents battery drain through the power supply, assuring maximum battery run time. Ballast lamp RT101 insures constant-current type battery charging while simultaneously providing full operating voltage to the instrument. The nickel-cadmium battery (BT101) provides the necessary operating potential (between 14.4 and 11 volts) for operation of the instrument removed from the power line.

SECTION 4

CALIBRATION

4-1 GENERAL

The calibration of the MV-928A is fairly simple, due to the fact that it is performed at a low frequency (approx. 200KC). This is possible because of the construction and performance of the diode cartridge, which exhibits an even response through the entire frequency range (10KC - 1.2GC). The 200KC calibration frequency was chosen mainly because it is in the flat portion of the total frequency range: well above the 10KC lower frequency limit of the meter and yet low enough to avoid possible calibration errors due to miterminations, standing waves, etc. It is, however, advisable, after the meter has been properly calibrated, to check its frequency response through the entire frequency range.

4-2 CALIBRATION PRECAUTIONS. (To avoid miscalibration, the following precautions should be observed):

A. Temperature Precautions. Although the probe is temperature compensated, it is recommended that the calibration be done at normal room temperature (75° F.), thus assuring the most effective temperature compensation.

B. Hum Pick-Up. Adequate hum shielding for the input leads of the monitoring voltmeter, must be provided, particularly on the 1mV and 3mV ranges, or serious errors may be introduced. If the monitoring meter is equipped with jack input terminals, a General Radio (Type GR-274-QB5) shield should be used in conjunction with this test cord to provide adequate shielding.

C. Battery Voltage. It is recommended that the battery voltage be in the Operate region whether the instrument is line or battery operated at the time of calibration.

4-3 CALIBRATION PROCEDURE FOR THE MV-928A

A. Calibration Equipment. Any signal generator capable of supplying a low distortion (less than 2%) 200KC sinusoidal signal, can be used to calibrate the MV-928A. To monitor the output of the generator, however, use of an external AC voltmeter with an accuracy of ± 1% or better is recommended.

B. Calibration Controls. Remove the rear cover plate from the cabinet to allow free access to "HI", "MID" and "LO" calibration controls. See Fig. 2-3 on page 8.

C. Mechanical Zero. Before turning on the instrument, adjust the mechanical zero screw to bring the meter pointer to the SET REF mark.

D. Electrical Zero. Adjustment is made by a front panel control marked "SET REF". This adjustment is effective only on 5 ranges, 1 mV through 100mV, and should be made with the probe attached to the instrument and terminated with a 50 Ω termination with the signal source de-energized. Recheck electrical zero occasionally during the calibration procedure.

E. Range Calibration. A three-point scale calibration procedure is employed for this instrument. The calibration points are: 1, low-end, 2, mid-scale and 3, the high end of scale. On the ranges employing the 1 to 3 scale, these points correspond to scale readings of "1", "2" and "3" respectively, while on the 3 to 10 scale the points are "3", "6" and "10". These points for calibration purposes are designated as LO, MID, and HI. Starting with the 3 volt range, apply a 2 volt 200KC signal (the MID scale point equivalent) to the instrument. Adjust the MID calibration control for the range selected to correspond to this input voltage. Next, apply a 1 volt signal (corresponding to the LO scale point) and adjust the LO control accordingly. Finally, a 3 volt signal (the HI scale value) is applied and the HI control adjusted. Due to the fact that some inter-action of the three controls takes place, this procedure should be repeated until proper tracking occurs at the three scale points. This procedure should be followed on the remaining ranges. Be certain to adjust the SET REF control on the five lower ranges before calibrating each of these ranges.

F. Scale Distribution. A close check at points other than the three calibration points may reveal some errors in the tracking accuracy of the meter. This situation will exist to a minor degree on almost all ranges of the instrument due to the basic non-linear response of the probe, as well as the non-linear correction network of the output circuit. However, the method described under 4-3E provides a tracking accuracy that is within the over-all specifications of the meter.

G. Frequency Response Check. To check the frequency response of the MV-928A, it will be necessary to use one or two signal generators to cover the entire frequency range of the instrument (10KC - 1.2GC). Care has to be taken to properly terminate the generators and line to avoid mistermination and standing wave errors. A recommended termination for this purpose consists of the 50 Ω bridging "N" tee adapter with the 50 Ω type "N" termination

4-4 CALIBRATION PROCEDURE FOR THE 100:1 CAPACITIVE DIVIDER (See Fig. 4-1).

The 100:1 divider is best calibrated by using a correctly calibrated MV-928A instrument. The accuracy of calibration of the divider will depend upon the accuracy of the RF voltmeter. With the capacitive divider inserted between the 50 Ω termination and RF probe, and the range selector set at 30mV, feed a 3V, 200KC signal into the probe and observe the meter reading. A properly calibrated divider will attenuate the RF signal exactly 100 times, resulting in a meter indication of 30mV. Any deviation from this reading can be corrected by slight adjustment of the hexagonal center contact screw at the front end of the divider. Always remove the termination each time an adjustment is made. Turning the screw in a clockwise direction will increase the meter reading. It is recommended that a #6 (3/16") hexagonal nut driver be used for this adjustment.

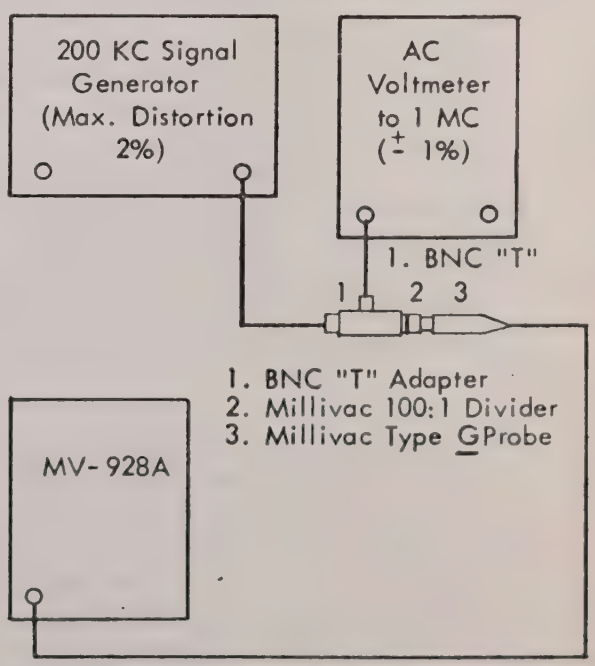

200 KC Signal Generator (Max. Distortion 2%)
AC Voltmeter to 1 MC (± 1%)
1. BNC "T"
1 2 3
1. BNC "T" Adapter
2. Millivac 100:1 Divider
3. Millivac Type G Probe
MV-928A

Fig. 4-1 - Calibration Equipment Set-Up

SECTION 5

MAINTENANCE

5-1 GENERAL

The following sections describe the usual maintenance procedure for both the instrument and the RF probe and accessories.

5-2 MAINTENANCE OF THE RF PROBE AND ACCESSORIES

5-2.1 RF Probe Cartridge Replacement

Replacement of the probe cartridge as a result of diode failure, due to excessive RF input, will probably be found to be the most frequent cause for service.

If the instrument does not respond to RF signals, but in other respects appears to be operating normally, the probe cartridge should be suspected. A simple check of the amplifier portion may be made by switching the instrument to its lowest range and rotating the "SET REF" control fully clockwise. The indicating meter should read approximately full scale if the amplifier is operating normally. A further check can be made by disconnecting the cable from the front panel. This should cause the pointer to drift off-scale in either direction as long as the range selector is in the 1mV position. When switched to the 3V position, the instrument should recover rapidly, with the pointer coming to rest at its "SET REF" position.

If the cartridge is suspected, a single resistance measurement of the diodes may be made after removal of the cartridge from the probe housing (see Fig. 5-1). This can be achieved by removal of the exposed set screw on the side of the probe housing. The cartridge may now be pulled out of the housing. Two small spring contacts will be noted on the end of the cartridge. Care should be exercised so as not to damage these contacts. By placing an ohmmeter across the contacts, a forward-reverse resistance ratio may be measured. Using a Simpson 260-VOM in its highest resistance range, a resistance ratio of approximately 800 should be noted with about 5K in the forward direction, when checking a good cartridge. An open circuit measurement definitely indicates a defective cartridge.

The replacement cartridge comes complete with a new grounding spring and set screw. The old spring should be removed from the probe housing and it may be reused if it is clean and not damaged. During manufacture, a thin, protective grease film has been applied to all silver-plated surfaces to retard oxidation and tarnishing and care should be exercised to avoid removal of this film. If the film has inadvertently been removed, or if the contacts inside the probe housing have been cleaned, a thin film of white vaseline may be applied to the surfaces. The new cartridge should be carefully inserted into the housing, making

certain that the slot in the side of the cartridge is aligned with the locking-screw hole in the side of the probe housing. The locking screw may now be inserted and tightened, taking care that it properly engages the cartridge slot. Finally, the grounding spring is inserted, noting the correct spring position, as shown in Fig. 5-1. Positioning the spring may be facilitated by gently pushing the cartridge all the way into the housing several times. When the spring is in its correct position, the fingers will be flush with the edge of the probe housing. With a little thumb pressure, the cartridge should slide smoothly back and forth against the spring-loaded socket assembly inside the probe housing. If it binds and does not return fully after being depressed, the grounding spring fingers may be holding it too tightly. Should this happen, the spring should be removed and the fingers flattened very slightly, pinching them between the smooth areas of a pair of long-nosed pliers.

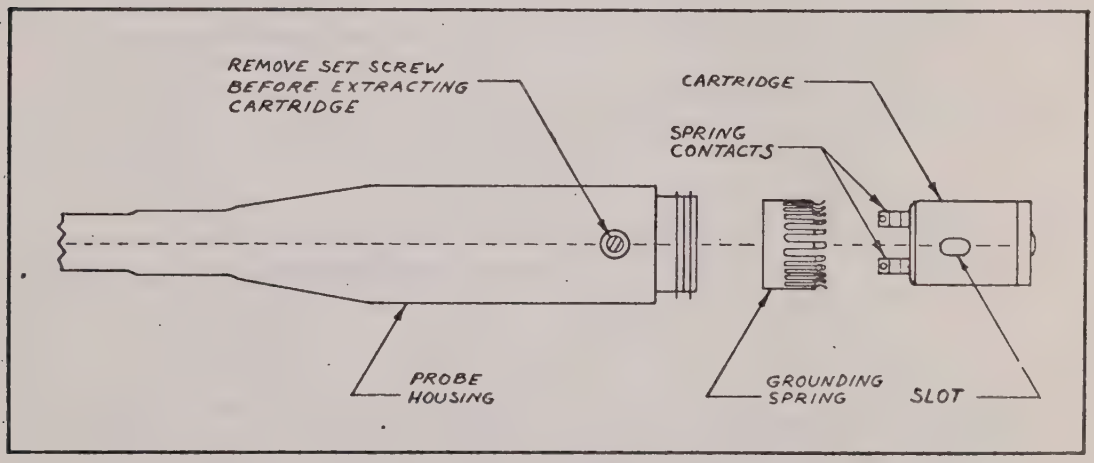


Fig. 5-1 Probe Cartridge Assembly

5-2.2 RF Probe Maintenance

The RF probe housing assembly is carefully manufactured and factory sealed. It is not recommended that the housing be disassembled. If it is found to be defective, it should be returned to the factory for repair. Warranty on the RF probe housing is void if it is tampered with. The probe housing may be checked out with an ohmmeter. The Millivac MV-77B or MV-279C is recommended for this purpose because of their accuracy and negligible power dissipation across the resistance to be measured. Assuming the probe and cable have been disconnected from the instrument, the RF cartridge should be removed before making the following measurements.

TABLE 1 - PROBE RESISTANCE MEASUREMENTS

Location	Resistance
P101A to P101B	Approx. 10K
P101A to P101C	" 100K
P101A to P101D	" 500K
(The above thermistor values are ± 20% at 72° F.)	
P101A to probe housing	Infinity
P101H to probe #1 terminal	10K ± 10%
P101 J to probe #2 terminal	10K ± 10%
P101H to P101J	Infinity
P101H to probe housing	"
P101 J " " "	"
P101E " " "	Less than 1 Ω
P101F " " "	" " "
P101K " " "	" " "

Any discrepancies in the above resistance checks indicate a defect in the probe housing assembly and it should be returned to Millivac for repair.

5-2.3 Probe Accessories

A. General: Maintenance is either self-explanatory or minor on most of the probe accessories available from Millivac. However, certain points of information noted here may be of value in the maintenance of this instrument. The center pins of all probe accessories, when threaded on the probe, should make contact within at least 1/16" of the fully threaded position.

B. High Impedance Tip. Check that the center pin is correctly positioned to make proper contact with RF probe center contact. Check the ground wire and clip for continuity.

C. Terminations. Check the DC resistance value of the film resistors. Terminations leave the factory at ± 1% of stated value. In most applications, the accuracy of the MV-77B is adequate for measuring this resistor in the field. If it is found to be out of tolerance, it is recommended that a new termination assembly be ordered from Millivac. See Section 6 for part number.

D. "Tee" Connector. These units are adjusted during manufacture for minimum VSWR and should not be disassembled.

E. 100:1 Capacitive Divider. Refer to calibration section for proper calibration of this unit. Damaged units are not readily serviced in the field. Return them to Millivac for repair.

5-3 MAINTENANCE OF THE INSTRUMENT

5-3.1 Cabinet Removal

Should the instrument require repairs which necessitate its removal from the cabinet, remove the rear calibration cover plate exposing 4-flat head Phillips 6-32 screws. Upon removing these screws (refer to Fig. 2-3 on page 8) slide the cabinet to the rear and off the instrument.

5-3.2 General Trouble-Shooting

A. Any of the printed circuit boards may be partially removed from the chassis by removing the 6-32 machine screws securing them to the chassis. (See Figs. 5-6 and 5-7). (It is recommended that the battery pack be removed from the chassis before servicing). It is also held in place by four 6-32 machine screws. The battery cable is sufficiently long enough to permit operation of the instrument with the battery outside of the chassis.

B. In case the instrument fails to operate on AC line, but operates on battery, investigation of the line cord and fuse should be made.

C. The fuse is located at the rear of the instrument (See Fig. 2-3 on page 8). Replace only with a "Slo-Blo" type of the correct rating, as marked on the rear nameplate above the fuse holder. Be certain that the line voltage switch, also located on the rear panel, is set to the correct position before operating.

D. If the instrument functions properly on AC line, but not on battery; and the battery checks out all right, the trouble may be a faulty ballast lamp, located at the rear of the instrument (See Fig. 2-3). It is recommended that the battery plug be disconnected before changing the ballast lamp. It is important that the lamp be replaced with one of the same type (#239).

E. If during battery operation, insufficient operating time is experienced between charges, the Power Supply Voltage Adjustment (R607) may be set too low. Before condemning the battery, check the charging voltage on the battery. Disconnect the battery plug and with the instrument operating on the 3 volt range, measure the voltage at the chassis mounted battery connector. This voltage should normally be set to 14.4 volts $\pm$ 2%. Under no circumstances, should this voltage ever be set to exceed 14.5 volts. Lower voltages than specified will result in an incompletely charged battery. Often, many more useful battery cycles can be obtained from a so-called "weak" battery, merely by a slight increase in the Voltage Adjustment Potentiometer. (See Fig. 5-4).

F. At this point, it is again stressed, that excessive discharging of the battery under load may cause reverse charging of one or more cells which can cause permanent damage to the battery, resulting in greatly reduced battery life. For maximum battery life, never allow the battery voltage to fall below the OPERATE region of the battery check scale on the indicating meter dial when operating the instrument.

G. If the instrument is not functioning properly and requires trouble shooting, the DC Modulator, Driver and transistors should be checked first, preferably by substitution. When checking the transistors by substitution, replace only with units of the same type and manufacture. Transistor Q301 may be ordered directly from Millivac, as well as the chopper G201 and driver A204. When the instrument is turned on, the chopper should produce a continuous audible 94 cps tone. If no chopper noise is evident, the chopper or its driver may be defective. Figs. 5-2, 5-3, 5-4 and 5-5 will be helpful in identifying and locating the various components of the MV-928A. Important static-voltage values and waveshapes with peak-to-peak voltage values are shown on the circuit schematics.

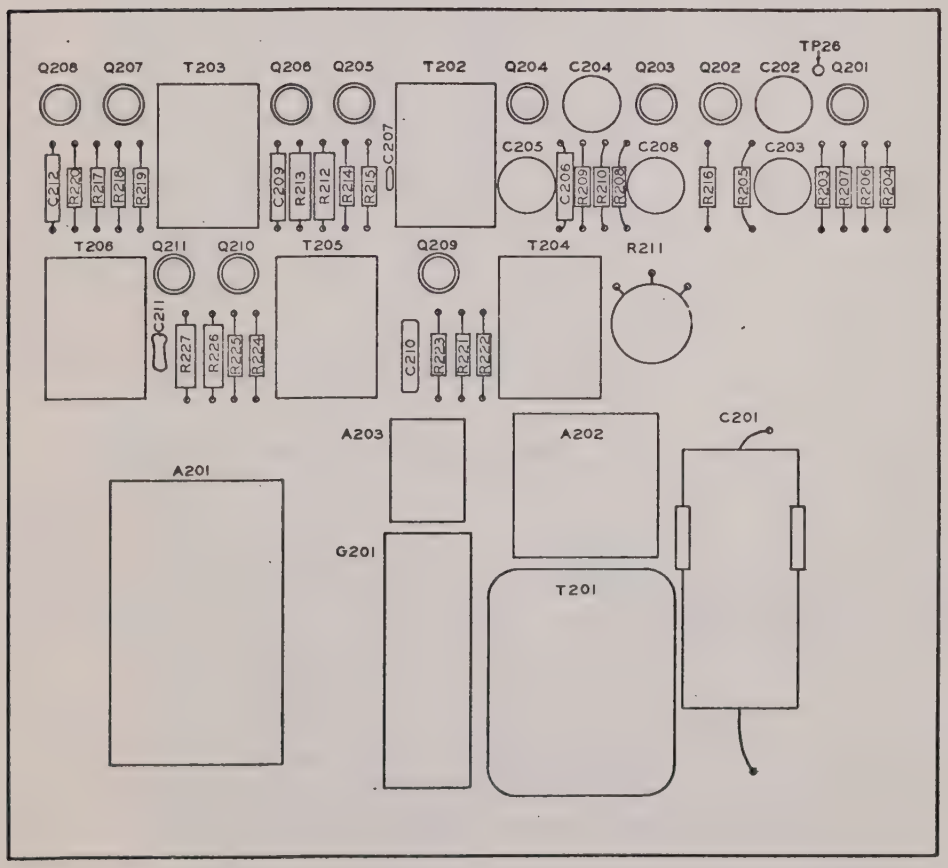


Fig. 5-2 Main Amplifier Board Assembly

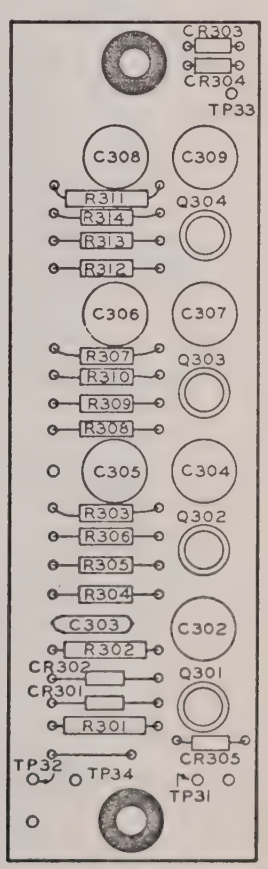


Fig. 5-3 Pre-Amp. Board Assembly

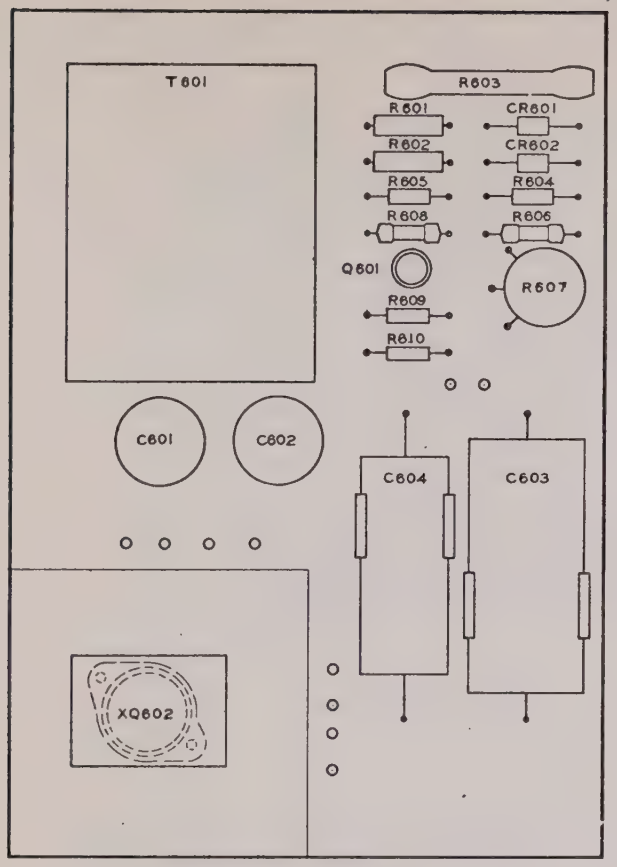


Fig. 5-4 Power Supply Board Assembly

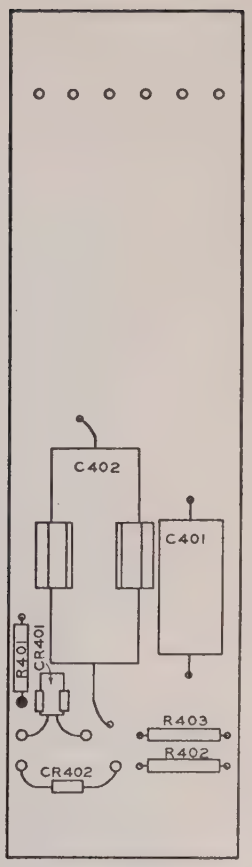


Fig. 5-5 Output Bd Assembly

5-3.3 Signal Tracing.

Assuming that a routine investigation by substitution has confirmed that the DC Modulator, its driver, and all transistors are good, signal tracing is the next approach.

Recommended service equipment consists of:

1 - DC VTVM, Millivac MV-127B or equal
1 - Tektronix Model 503 scope or equal
1 - AC VTVM (RMS), Millivac MV-45A or equal
1 - 200KC Signal Generator H/P 606A or equal

When operating the instrument removed from its cabinet, care must be exercised in avoiding power line hum pick-up in the chopper and pre-amplifier circuits. Excessive pick-up will prevent making useful gain and waveshape measurements. If pick-up is a problem, aluminum plates placed on the bottom, top and amplifier side of the instrument will effectively shield the instrument.

Be certain that the power supply voltage is set at 14.4 volts before making any gain measurements, or variations may result. See Section 5-3.2, Par. E.

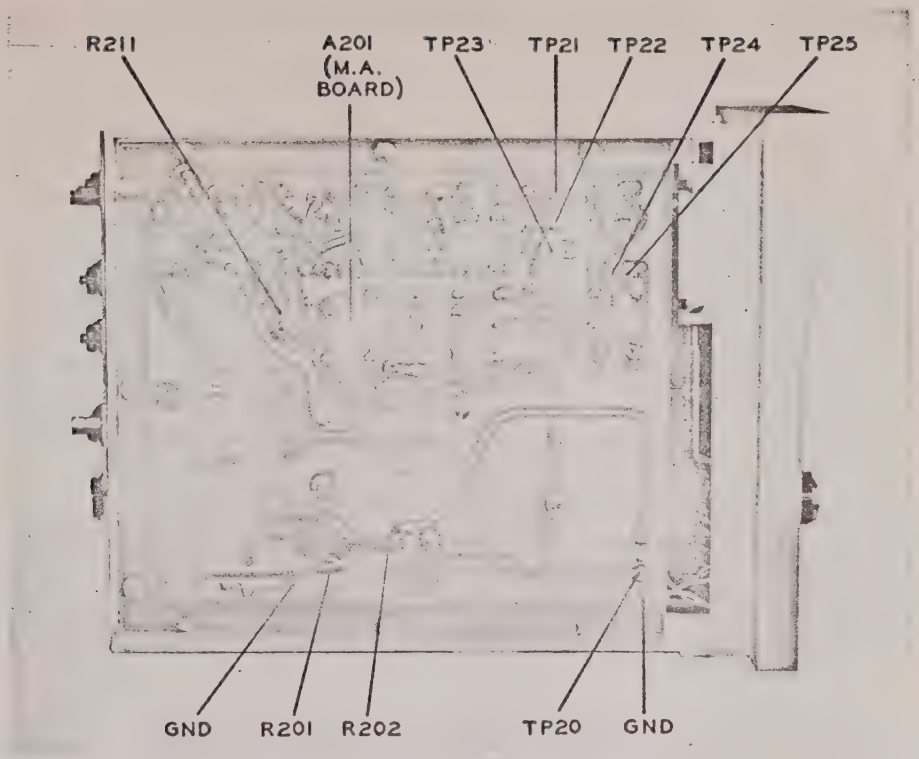


Fig. 5-6 Left Side View of MV-928A

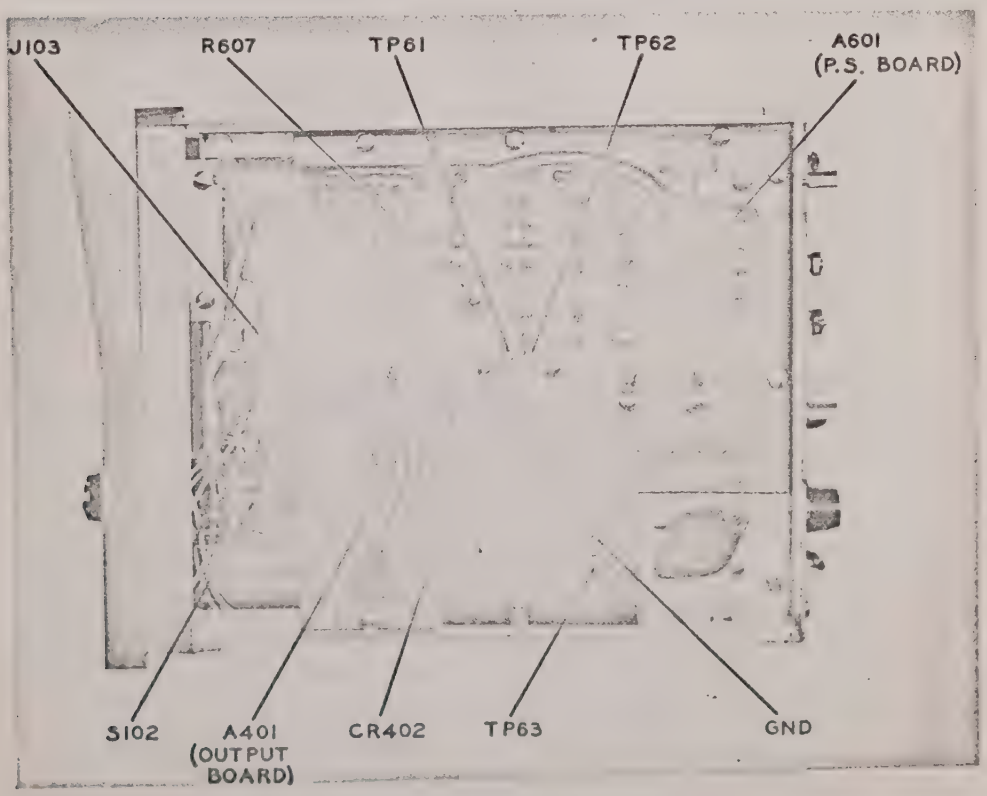


Fig. 5-7 Right Side View of MV-928A

A. Checking Waveshape of Complete Amplifier. If the meter is operative at all, although somewhat erratic or intermittent, improper chopper action or other amplifier weaknesses may be detected by observation of the chopped and amplified signal at the secondary winding of the output transformer test point, TP 21 or TP 23 and chassis ground (See circuit schematic of main amplifier and Fig. 5-6). A check of the output waveshape can be made by feeding a 10mV, 200KC, RF signal into the probe with the range switch in the 10mV position. Without the RF input signal and the instrument properly zeroed to the "SET REF" position, the wave shape appears as shown in the circuit schematic of the main amplifier. The residual signal appearing in the zero-signal wave shape is not entirely amplifier noise. Its spikes and depressions are caused by the 94 cps reference signals impressed upon the bases of Q207 and Q208. Any drastic deviations of either wave shape indicates a faulty amplifier. Improper adjustment of the zero control "SET REF" may result in large deviations from the wave shapes illustrated.

The reference amplifier output signal must be of the correct amplitude and wave shape for proper operation. The wave shape can be observed across TP 24 and TP 25. (See Fig. 5-6). If the scope is tied to the power line, the instrument should be battery operated and isolated from ground. The wave shape and amplitude should agree closely with that shown on the Reference Amplifier schematic.

B. Checking Chopper and Pre-amplifier Stages. Locate test point, TP 33, on pre-amplifier board (See Fig. 5-3) and unsolder the brown lead connected to it. This disconnects the output of the pre-amplifier from the main amplifier. The wave shape of the amplified, chopped signal at TP 33, can be observed, as seen on the pre-amplifier circuit schematic.

Two wave shape values are shown. One is with zero input signal while the other is with a 1mV DC signal applied between TP 20 and ground (See Fig. 5-6). With 1mV DC input, the output of the pre-amplifier should be approximately 1 volt, peak-to-peak, at 94 cps and should be essentially a square wave. Any drastic deviations in amplitude and wave shape indicates an abnormality in this portion of the instrument. Transistors are checked best by substitution. Be certain to replace only with units of the same type and manufacture.

C. Checking the Main Amplifier. With the amplifier set-up as in 5-3.4B disconnect one end of diode CR402 (glass diode located on output board). See Fig. 5-5. A test set-up as shown in Fig. 5-8 should be constructed which furnishes the necessary input signal to drive the meter to full scale. In making this measurement, the reference amplifier must be functioning properly with the correct output amplitude and wave shape, as shown on main amplifier schematic. With the test source switched off, carefully adjust the SET REF control to zero the meter at the SET REF point on the meter scale. Now switch on the test source, supplying the correct input signal to the main amplifier via TP 26. (See Fig. 5-2). The meter should now slowly move upscale and if the amplifier has the correct gain, the meter will read approximately full scale. If the reading is in error by more than $\pm$ 10% of full scale, the amplifier gain control, R211, can be adjusted for a full scale meter reading. This adjustment should occur at a point between 25 and 75% of the controls rotation.

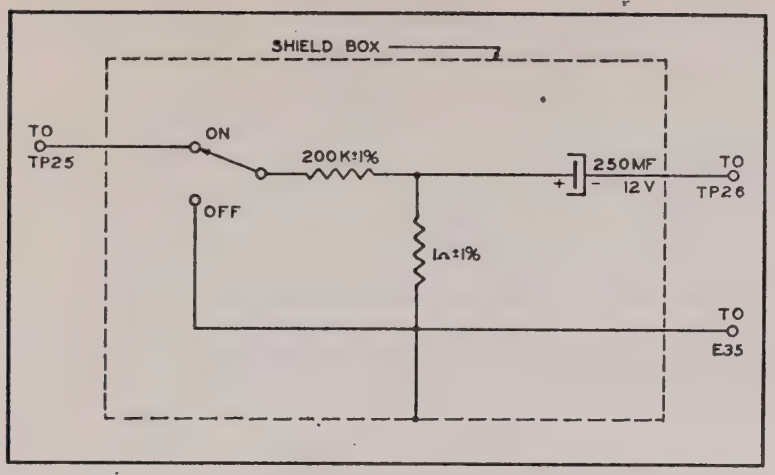


Fig. 5-8 Test Set-up

If excessive gain is necessary or the meter cannot be made to read full scale it indicates a faulty amplifier and the transistors in the associated circuit should be checked. It is important to replace only with the same type and manufacture.

When the above adjustments are correct the instrument can be restored to its normal condition by resoldering the brown lead to test point TP 33 and resoldering diode CR402. The instrument's calibration should now be checked before placing it back in service.

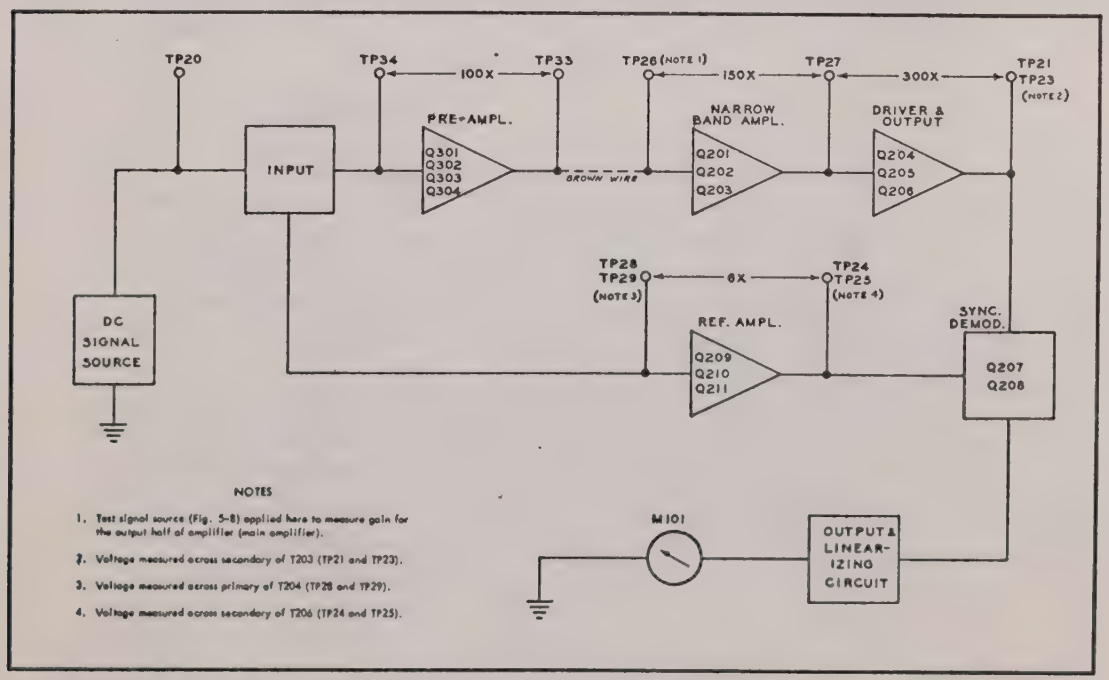


Fig. 5-9 Amplifier AC Voltage Gain Diagram

5-3.4 Plug-in Filters (Removal and Replacement)

Two plug-in filter modules are employed in this instrument. A202, the Input Filter provides at least 50 db rejection to the frequency marked on its case. A203, the Amplifier Filter has at least 40 db rejection at the frequency marked on its case. This frequency must agree with the chopper and chopper drive frequencies. These filters may be easily removed from the circuit board by removing the 4-40 retaining screws at the center of the module on the printed circut side of the board. (See Fig. 5-6). After removing the screw, gently pull the module away from the board avoiding bending of the pins. The filter's performance can be measured easily when removed from the board or if a filter of another frequency is desired, it can be readily plugged into the board. When reinstalling filters, be certain to secure with the 4-40 retaining screw.

5-3.5 Chopper and Driver (Removal - Replacement)

A printed circuit plug-in type chopper and driver are employed in this circuit. They must be replaced only by units of the same type and manufacture. It is recommended that they be obtained from Millivac, where they are tested and checked for performance in Millivac Instruments. The chopper is secured by a 4-40 hex nut accessible on the printed circuit side of the board directly underneath the chopper (See Fig. 5-6). The driver is secured by a hold down clip. It is only necessary to loosen the 4-40 screw holding the clip to the board. The clip may now be rotated away from the driver, allowing it to be removed from the board. Care must be exercised when removing these units so as to prevent bending of the pins. Be certain to properly secure these units when reinstalling on the board.

5-3.6 Power Supply

The output of the power transformer T601 is rectified by diodes CR601 and CR602 in a full wave center-tapped configuration. The resultant DC is limited by R603 and regulated by the series transistor Q601. The adjustable voltage divider R606, R608 and potentiometer R607, sets the bias on the voltage Reference Amplifier Q602 whose output controls the bias on Q601, the series regulator. The output of the power supply can be varied from approximately 11 volts to 18 volts by R607. With the instrument as the only load (approximately 95mA) and the voltage set to 14.4 volts, the power supply should regulate with as little as approximately 80 volts AC input. When measuring the power supply ripple with an oscilloscope, be certain the line voltage is near 117 volts AC. The ripple voltage wave shape is shown on the Power Supply schematic. The scope should be connected to TP 61 with the ground connection at power supply ground test point. (See Fig. 5-7).

SECTION 6

REPLACEABLE PARTS LIST

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
A1 thru			
A100	Not assigned		
A101	Ass'y, probe cartridge (Part of P101	900-2004	
A102	Ass'y, termination adapter, 50 Ω	900-2050	
A103 thru			
A200	Not assigned		
A201	Ass'y, etched circuit board, Main Amplifier	450-1011	
A202	Ass'y, input filter	450-1007	
A203	Ass'y, Amplifier filter	450-1008	
A204	Ass'y DC Modulator Driver (94 cps)	700-1006	
A205 thru			
A300	Not assigned		
A301	Ass'y, etched circuit board, Pre-amplifier	450-1010	
A302 thru			
A400	Not assigned		
A401	Ass'y, etched circuit board, Output	450-1006	
A402 thru			
A500	Not assigned		
A501	Ass'y, etched circuit board, Calibration controls	450-1009	
A502 thru			
A600	Not assigned		
A601	Ass'y, etched circuit board, Power Supply	450-1012	
BT1 thru			
BT100	Not assigned		
BT101	Battery, nickel cadmium, 12V DC (including P103)	460-1000	
C1 thru			
C100	Not assigned		
C101	Capacitor, ceramic, disc .002 µfd, 1000V	610-1006	Centralab DD202
C102 thru			
C109	Same as C101		
C110 &			
C111	Capacitor, ceramic, disc .01 µfd, 500V	610-1009	Erie ED-.01
C112 thru			
C200	Not assigned		
C201	Capacitor, electrolytic, 2000 µfd, 15V	640-1011	Illinois SMT-2000M 15V
C202	Capacitor, electrolytic, 100 µfd, 12V	635-1012	Sprague VL 1140

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
C203 thru C205	Same as C202		
C206 & C207	Same as C101		
C208	Capacitor, electrolytic, 90 µfd, 15V	635-1013	Sprague V6 1180
C209	Capacitor, paper, metalized, 0.1 µfd, 200V	630-1002	Hopkins P12D
C210	Same as C101		
C211	Capacitor, ceramic, 220 µµfd, 600V	600-1003	Centralab D6-221
C212	Same as C209		
C213 thru C301	Not assigned		
C302	Same as C202		
C303	Same as C209		
C304 thru C309	Same as C202		
C310 thru C400	Not assigned		
C401	Capacitor, paper, metalized, 1.0 µfd, 200	630-1005	Astron MVL-2-1M
C402	Capacitor, electrolytic, 1000 µfd, 15V	640-1010	Illinois 1000 M 15V
C403 thru C600	Not assigned		
C601	Capacitor, electrolytic, 250 µfd, 50V	650-1005	Illinois SMTU 250M 50V
C602	Same as C601		
C603	Same as C201		
C604	Same as C402		
CR1 thru CR100	Not assigned		
CR101	Diode	101-2000	Sarkes 1N2482
CR102 thru CR300	Not assigned		
CR301	Diode	101-0252	Transistor 1N252
CR302 thru CR304	Same as CR301		
CR305	Diode, zener	101-2001	Hoffman 1N706
CR306 thru CR400	Not assigned		
CR401	Diode	101-2002	
CR402	Diode	101-3000	
CR403 thru CR600	Not assigned		
CR601 & CR602	Same as CR101		

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
DS1 thru			
DS100	Not assigned		
DS101	Lamp, pilot AC	800-3001	Drake R118-604
F1 thru			
F100	Not assigned		
F101	Fuse, cartridge, S-B, 3/10 AMP	800-1006	Bus - MDL
G2 thru			
G200	Not assigned		
G201	Chopper, electro-mechanical, S. P. D. T. 94 cps	700-1005	
J1 thru			
J100	Not assigned		
J101	Connector, chassis, female, INPUT	800-7220	Amphenol 165-16
J102	Jack, telephone, OUTPUT	800-7500	Switchcraft 24-SF
J103	Connector, battery, male, 2 pin	800-7404	Cinch-Jones P302AB
J104	Not assigned		
J105	Connector, power, male, 3 pin		
M1 thru			
M100	Not assigned		
M101	Meter, indicating, 0-500μ A	203-1104	
P1 thru			
P100	Not assigned		
P101	Probe, (Type G) including, housing cartridge, cable and connector	900-2000	Millivac
P102	Not assigned		
P103	Connector, battery, female including cable (part of BT101)	800-7405	Cinch-Jones S302CCT
P104	Line cord set, power, removable	800-5121	Belden 17258S
P105	Part of P104		
Q1 thru			
Q200	Not assigned		
Q201	Transistor, Ge, PNP, 2N508A	100-1006	GE 2N508A
Q202	Same as Q201		
Q203	Same as Q201		
Q204	Transistor, Ge, PNP, 2N1413	100-1007	GE 2N1413
Q205	Transistor, Ge, PNP, 2N1414	100-1008	GE 2N1414
Q206	Same as Q205		
Q207	Same as Q204		

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
Q208	Same as Q204		
Q209	Same as Q204		
Q210	Same as Q204		
Q211	Same as Q204		
Q212 thru			
Q300	Not assigned		
Q301	Transistor, Si, NPN	100-1005	
Q302	Transistor, Ge, PNP, 2N414	100-1004	Industro 2N414
Q303	Same as Q302		
Q304	Same as Q302		
Q305 thru			
Q600	Not assigned		
Q601	Transistor, Ge, PNP, 2N459A	100-1009	Motorola 2N459A
Q602	Transistor, Si, RA1	100-1010	GE RA2
R1 thru			
R100	Not assigned		
R101	Resistor, fxd, dep. carbon, 5M ± 1%, 1/2W	520-5004	
R102	" " " " 1M " " "	520-1004	
R103	" " " " 2.15M " " "	520-2154	
R104	Same as R101		
R105**	Resistor, fxd, dep. carbon, 250K ± 1%, 1/2W	520-2503	
R106**	" " " " 48K " " "	520-4802	
R107**	" " " " 7.5K " " "	520-7501	
R108**	" " " " 1.9K " " "	520-1901	
R109**	" " " " 1.3K " " "	520-1301	
R110	Not assigned		
R111	Resistor, fxd, dep. carbon, 1.5M ± 1%, 1/2W	520-1504	
R112	Same as R106		
R113	Resistor, fxd, dep. carbon, 35K ± 1%, 1/2W	520-3502	
R114	" " " " 14K " " "	520-1402	
R115	" " " " 4K " " "	520-4001	
R116	" " comp. 620K ± 10%, "	500-624	
R117	" variable, comp. linear taper, 1M to 10%, 1/2W	580-1030	
R118	" fxd, dep. carbon, 28K ± 1%, 1/2W	520-2802	
R119	" " " " 2K ± 1%, 1/2W	520-2001	
R120 thru			
R200	Not assigned		
R201	Resistor, fxd, WW 25 Ω ± 1%, 1/2W	520-25ROW	

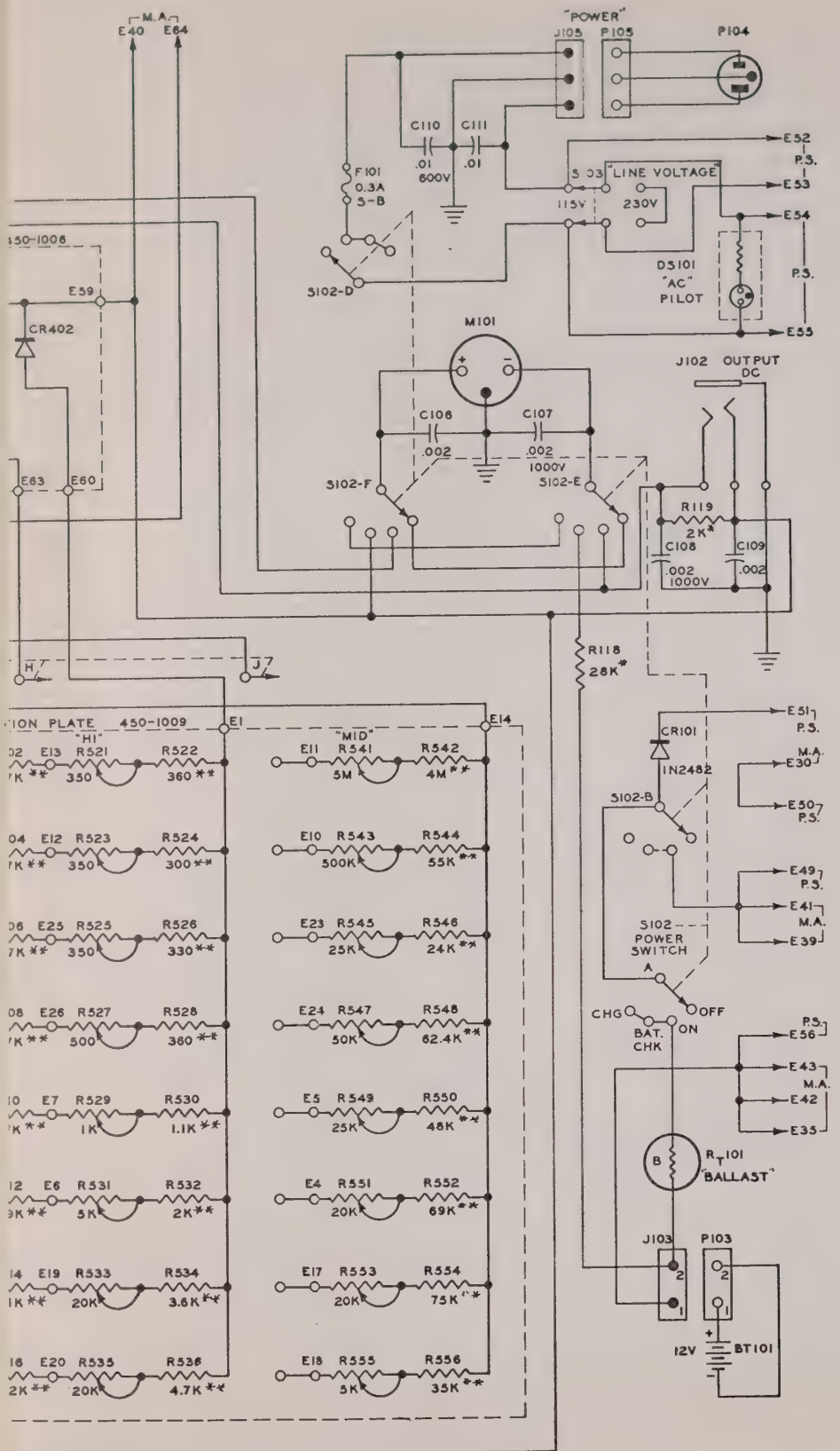
** Selected in manufacture; nominal value listed.

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R202	Resistor, fxd, dep. carbon, 1K to 1%, 1/2W	520-1001	
R203	" " comp., 3.3K to 10%, 1/2W	500-332	
R204	" " " 82K " " "	500-823	
R205	" " " 10K " " "	500-103	
R206	Same as R205		
R207	Resistor, fxd, comp., 390 Ω ± 10%, 1/2W	500-391	
R208	Same as R205		
R209	Same as R205		
R210	Same as R204		
R211	Resistor, variable, carbon, linear taper, 1K ± 30%, 1/4 W	580-1018	
R212	Resistor, fxd, WW, 8.2 Ω ± 10%, 1/2W	510-8R2	
R213	Same as R212		
R214	Resistor, fxd, comp., 47 Ω ± 10%, 1/2W	500-470	
R215	" " " 4.7K " " "	500-472	
R216	" " " 27 Ω " " "	500-270	
R217	Same as R204		
R218	Same as R204		
R219	Resistor, fxd, comp., 27K ± 10%, 1/2W	500-273	
R220	Same as R219		
R221	Resistor, fxd, comp., 1K ± 10%, 1/2W	500-102	
R222	" " " 8.2K " " "	500-822	
R223	Same as R221		
R224	Same as R215		
R225	Same as R216		
R226	Resistor, fxd, WW, 2.2 Ω ± 10%, 1/2 W	510-2R2	
R227	Same as R226		
R228 thru R300	Not assigned		
R301	Resistor, fxd, dep. carbon, 25 Ω ± 1%, 1/2W	520-25RO	
R302	" " " " 5K ± 1%, 1/2W	520-5001	
R303	Same as R203		
R304	Resistor, fxd, comp., 22K ± 10%, 1/2W	500-223	
R305	Same as R205		
R306	Same as R221		
R307	Same as R203		
R308	Same as R304		
R309	Same as R205		
R310	Same as R221		
R311	Resistor, fxd, dep. carbon, 3.5K to 1%, 1/2W	520-3501	
R312	Same as R304		
R313	Same as R205		
R314	Same as R221		

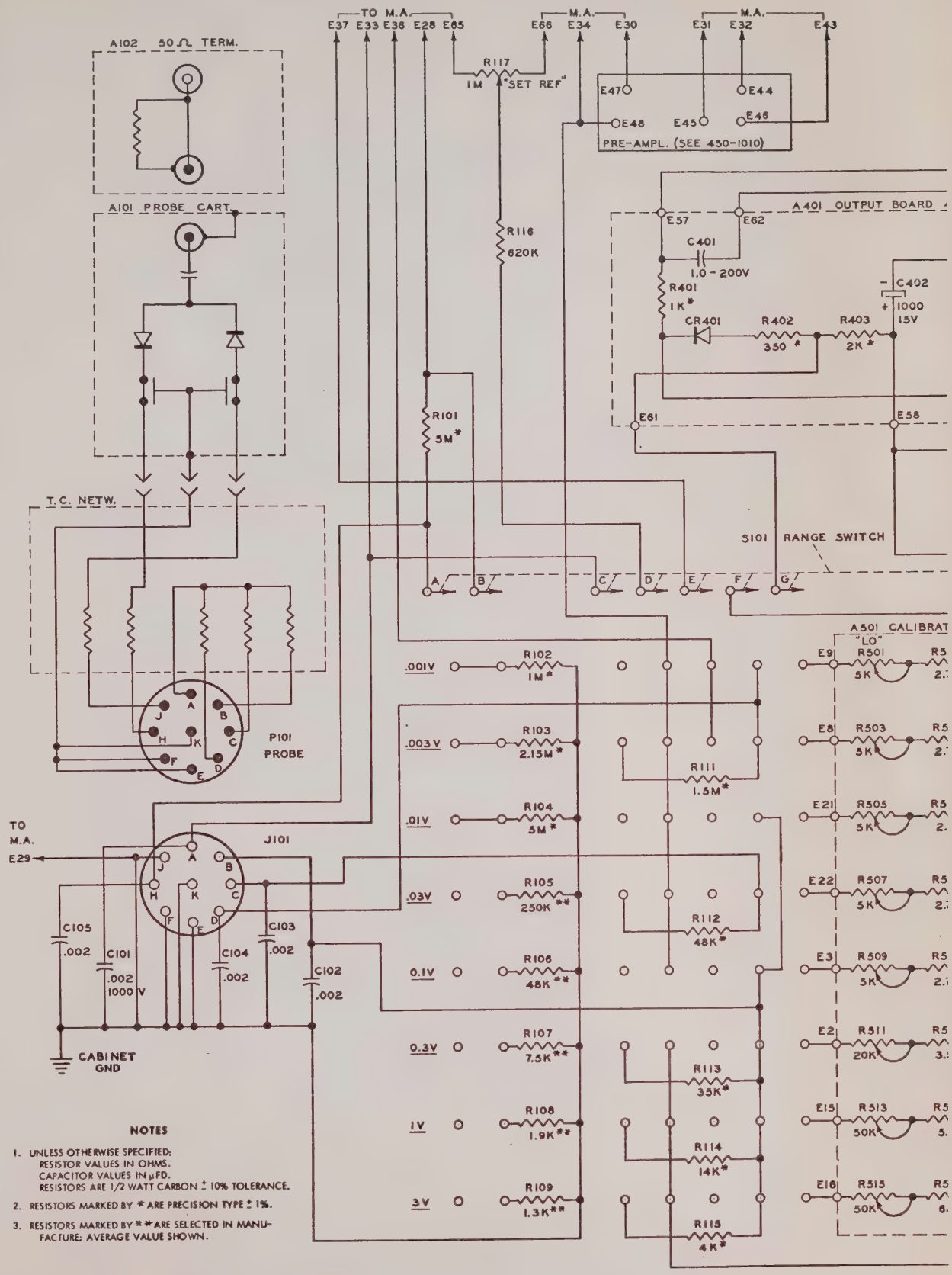
CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R315 thru			
R400	Not assigned		
R401	Same as R202		
R402	Resistor, fxd, dep. carbon, 350 Ω ± 1%, 1/2W	520-3500	
R403	Same as R119		
R404 thru			
R500	Not assigned		
R501	Resistor, variable, carbon, linear tapes, 5K ± 30%, 1/4W	580-1019	
R502	Resistor, fxd, comp., 2.7K ± 10%, 1/2W	500-272	
R503	Same as R501		
R504	Same as R502		
R505	Same as R5-1		
R506	Same as R502		
R507	Same as R501		
R508	Same as R502		
R509	Same as R501		
R510	Same as R502		
R511	Resistor, variable, carbon, linear tapes, 20K ± 30%, 1/4W	580-1020	
R512	Resistor, fxd, comp., 3.9K ± 10%, 1/2W	500-392	
R513	Resistor, variable, carbon, linear tapes, 50K to 30%, 1/4W	580-1021	
R514	Resistor, fxd, comp. 5.1K ± 10%, 1/2W	500-512	
R515	Same as R513		
R516	Resistor, fxd, comp. 6.2K ± 10%, 1/2W	500-622	
R517 thru			
R520	Not assigned		
R521	Resistor, variable, carbon, linear tapes, 350 Ω ± 30%, 1/4W	580-1023	
R522	Resistor, fxd, comp., 360 Ω ± 10%, 1/2W	500-361	
R523	Same as R521		
R524	Resistor, fxd, comp., 300 Ω ± 10%, 1/2W	500-301	
R525	Same as R521		
R526	Resistor, fxd, comp. 330 Ω ± 10%, 1/2W	500-331	
R527	Resistor, variable, carbon, linear tapes, 500 Ω ± 30%, 1/4W	580-1022	
R528	Same as R522		
R529	Resistor, variable, carbon, linear tapes, 1K ± 30%, 1/4W	580-1024	
R530	Resistor, fxd, comp., 1.1K ± 10%, 1/2W	500-112	
R531	Same as R501		
R532	Resistor, fxd, comp., 2K ± 10%, 1/2W	500-202	
R533	Same as R511		

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
R534	Resistor, fxd, comp., 3.6K ± 10%, 1/2W	500-362	
R535	Same as R511		
R536	Same as R215		
R537 thru R540	Not assigned		
R541	Resistor, variable, carbon, linear tapes, 5M ± 30%, 1/4W	580-1027	
R542	Resistor, fxd, dep. carbon, 4M ± 1%, 1/2W	520-4004	
R543	Resistor, variable, carbon, linear tapes, 500K ± 30%, 1/4W	580-1026	
R544	Resistor, fxd, dep. carbon, 55K ± 1%, 1/2W	520-5502	
R545	Resistor, variable, carbon, linear tapes, 25K ± 30%, 1/4W	580-1025	
R546	Resistor, fxd, dep. carbon, 24K ± 1%, 1/2W	520-2402	
R547	Same as R513		
R548	Resistor, fxd, dep. carbon, 62.4K ± 1%, 1/2W	520-6242	
R549	Same as R545		
R550	Resistor, fxd, dep. carbon, 48K ± 1%, 1/2W	520-4802	
R551	Same as R511		
R552	Resistor, fxd, dep. carbon, 69K ± 1%, 1/2W	520-6902	
R553	Same as R511		
R554	Resistor, fxd, dep. carbon, 75K ± 1%, 1/2W	520-7502	
R555	Same as R501		
R556	Same as R113		
R557 thru R600	Not assigned		
R601	Resistor, fxd, WW, 1 Ω ± 10%, 1/2W	510-1R0	
R602	Same as R601		
R603	Resistor, fxd, WW, 25 Ω ± 10%, 10W	560-1002	
R604	Same as R215		
R605	Same as R215		
R606	Resistor, fxd, dep. carbon, 1.5K ± 1%, 1/2W	520-1501	
R607	Same as R211		
R608	Same as R606		
R609	Resistor, fxd, comp., 510 Ω ± 10%, 1/2W	500-511	
R610	Same as R609		
R_T1 thru R_T100	Not assigned		
R_T101	Lamp, ballast	110-3003	CM239
S1 thru S100	Not assigned		
S101	Switch, rotary, RANGE (complete ass'y.)	420-1014	

CKT SYM	Description	Millivac Part No.	Manufacturer & Mfr's. Part No.
S102	Switch, rotary, Power	400-1014	
S103	Switch slide, D. P. D. T.	400-1015	
T1 thru T200	Not assigned		
T201	Transformer, input, Chopper	300-3001	Triad G22
T202	" interstage	300-2008	
T203	Same as T202		
T204	Transformer, input	300-2007	
T205	Same as T202		
T206	Same as T202		
T207 thru T600	Not assigned		
T601	Transformer, power	300-4008	
	Miscellaneous		
	Fuseholder	800-2100	Bus HKP
	Knob, bar, w/skirt, RANGE	800-4128	Buckeye PS-95BL-S2
	Knob, w/skirt, Power	800-4129	
	Knob, SET REF	800-4126	Buckeye PS-70D-2
	Plug, telephone, OUTPUT	800-7800	Switchcraft #60
	Tip, high impedance	900-2002	
	Optional		
	100:1 Capacitive voltage divider	900-2010	
	Adapter, bridging, type N "tee"	900-2020	
	Termination, BNC, open circuit	900-2100	



SCHEMATIC DIAGRAM OF MV-928A - Attenuator, Switching, Output, Meter and Interconnecting Circuits



NOTES

1. UNLESS OTHERWISE SPECIFIED:
   RESISTOR VALUES IN OHMS.
   CAPACITOR VALUES IN μFD.
   RESISTORS ARE 1/2 WATT CARBON ± 10% TOLERANCE.
2. RESISTORS MARKED BY * ARE PRECISION TYPE ± 1%.
3. RESISTORS MARKED BY ** ARE SELECTED IN MANUFACTURE; AVERAGE VALUE SHOWN.

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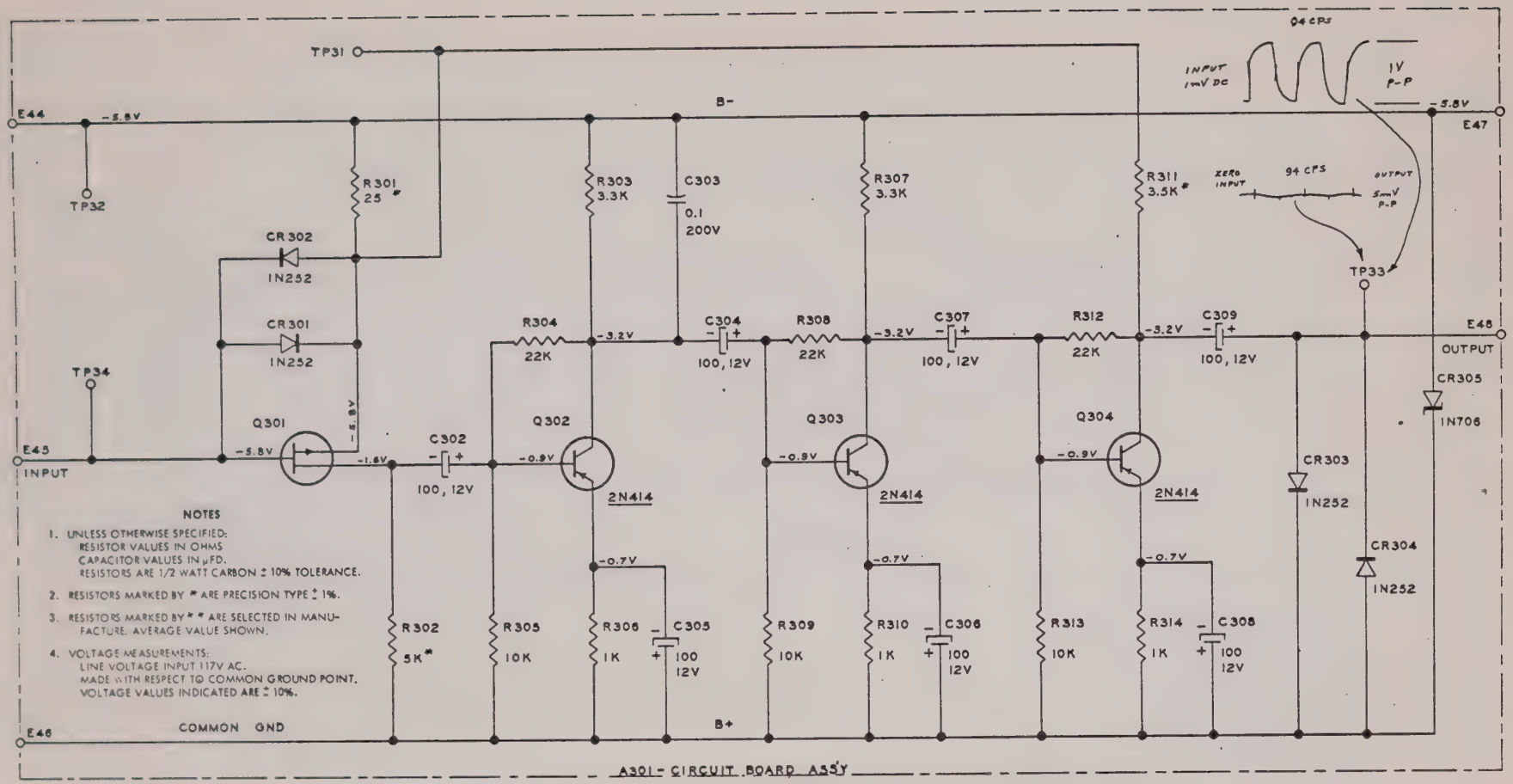

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3. RESISTORS MARKED BY ** ARE SELECTED IN MANUFACTURE. AVERAGE VALUE SHOWN.
4. VOLTAGE MEASUREMENTS:
   LINE VOLTAGE INPUT 117V AC.
   MADE WITH RESPECT TO COMMON GROUND POINT.
   VOLTAGE VALUES INDICATED ARE ± 10%.

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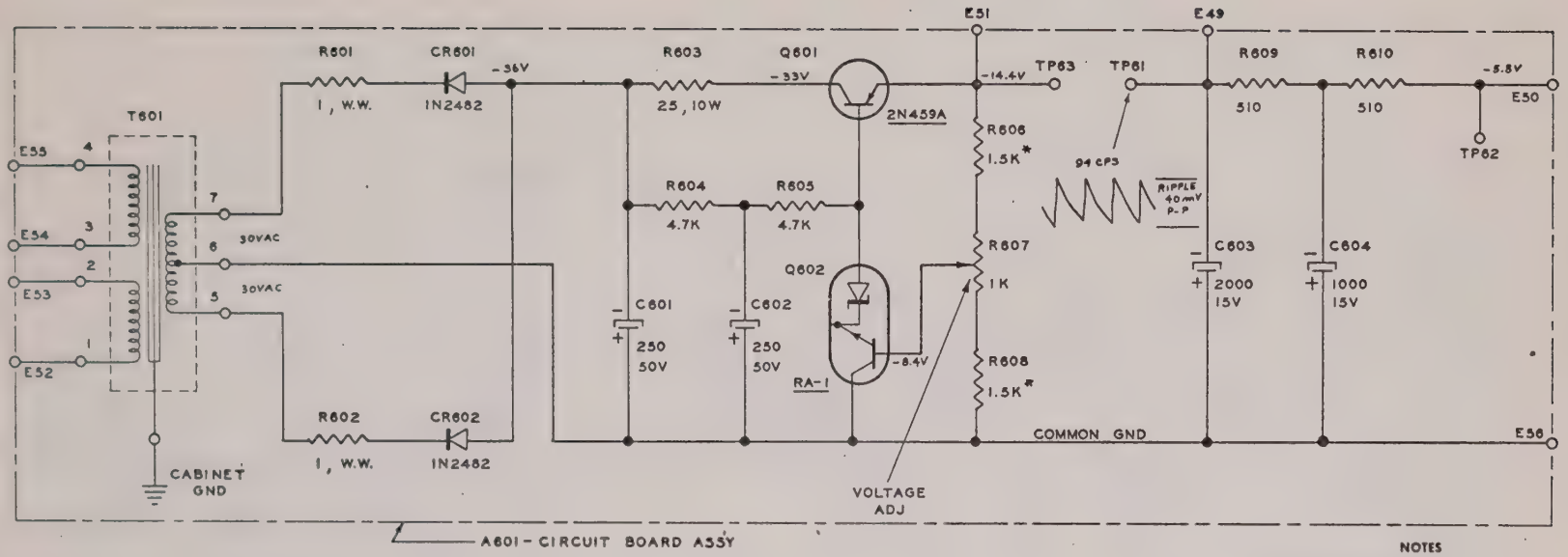
Millivac Instruments, Inc.

PRE - AMPLIFIER - SCHEMATIC NO. 450-1010

3-65



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   CAPACITOR VALUES IN μFD.
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2. RESISTORS MARKED BY * ARE PRECISION TYPE ± 1%.
3. RESISTORS MARKED BY * * ARE SELECTED IN MANUFACTURE; AVERAGE VALUE SHOWN.
4. VOLTAGE MEASUREMENTS:
   LINE VOLTAGE INPUT 117V AC.
   MADE WITH RESPECT TO COMMON GROUND POINT.
   VOLTAGE VALUES INDICATED ARE ± 10%.

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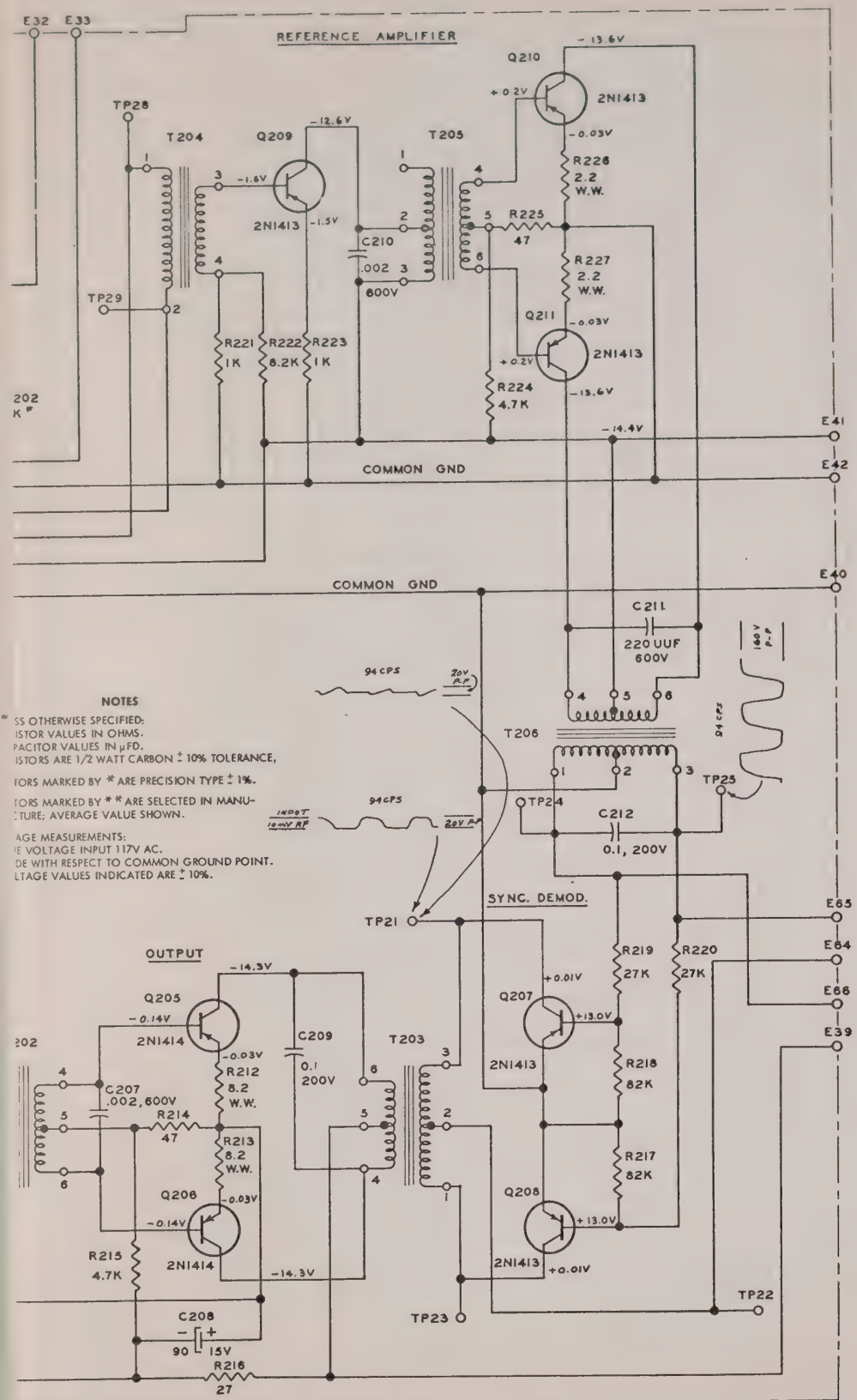
Millivac Instruments, Inc.

REG. POWER SUPPLY - SCHEMATIC NO. 450-1012

3-65



NOTES

SS OTHERWISE SPECIFIED:
ISTOR VALUES IN OHMS.
PACITOR VALUES IN μFD.
ISTORS ARE 1/2 WATT CARBON ± 10% TOLERANCE,

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TORS MARKED BY * * ARE SELECTED IN MANU-
CTURE; AVERAGE VALUE SHOWN.

AGE MEASUREMENTS:
IE VOLTAGE INPUT 117V AC.
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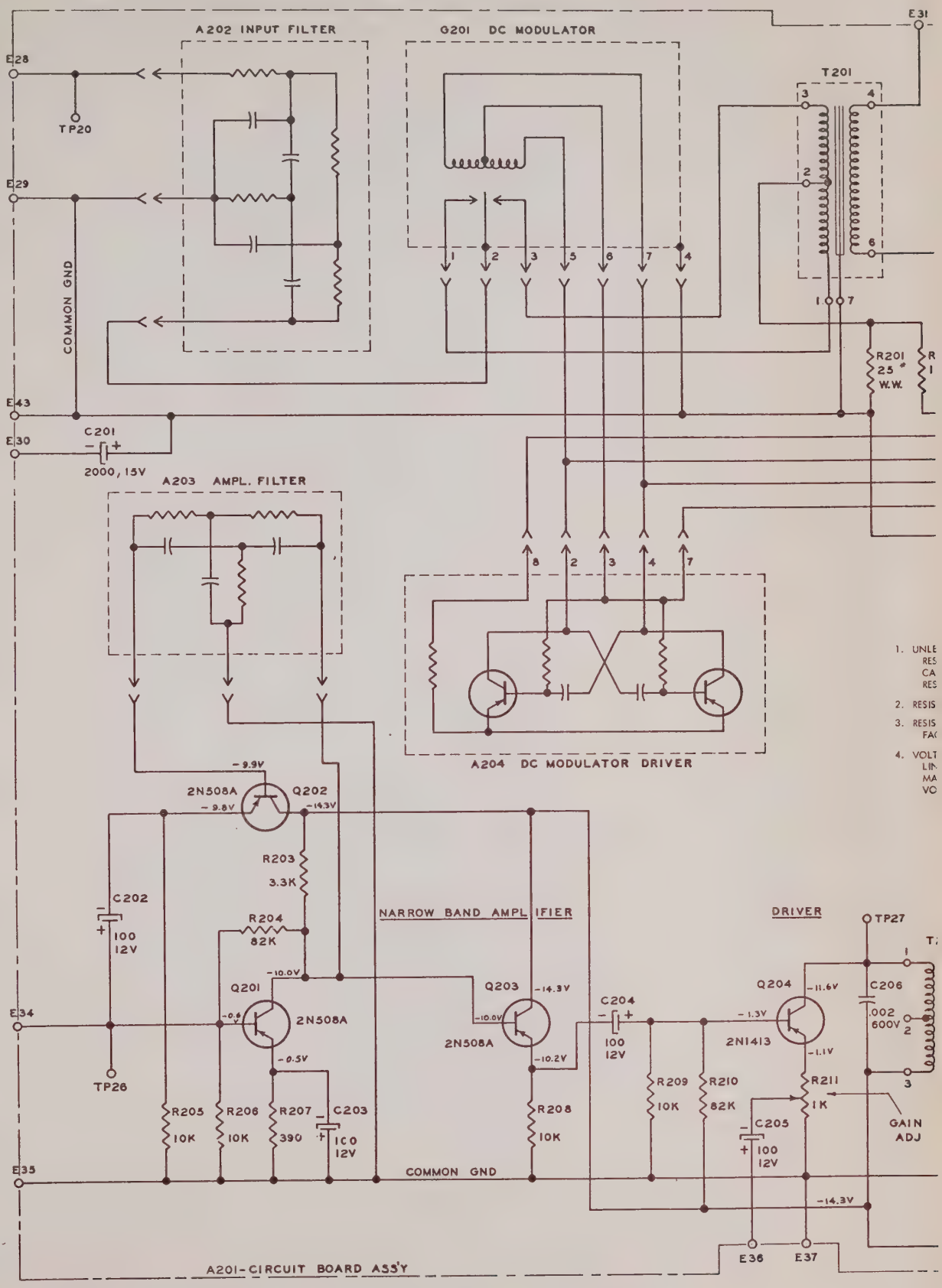
nstruments, Inc.

MAIN AMPLIFIER - SCHEMATIC NO. 450-1011

Rev 6-65



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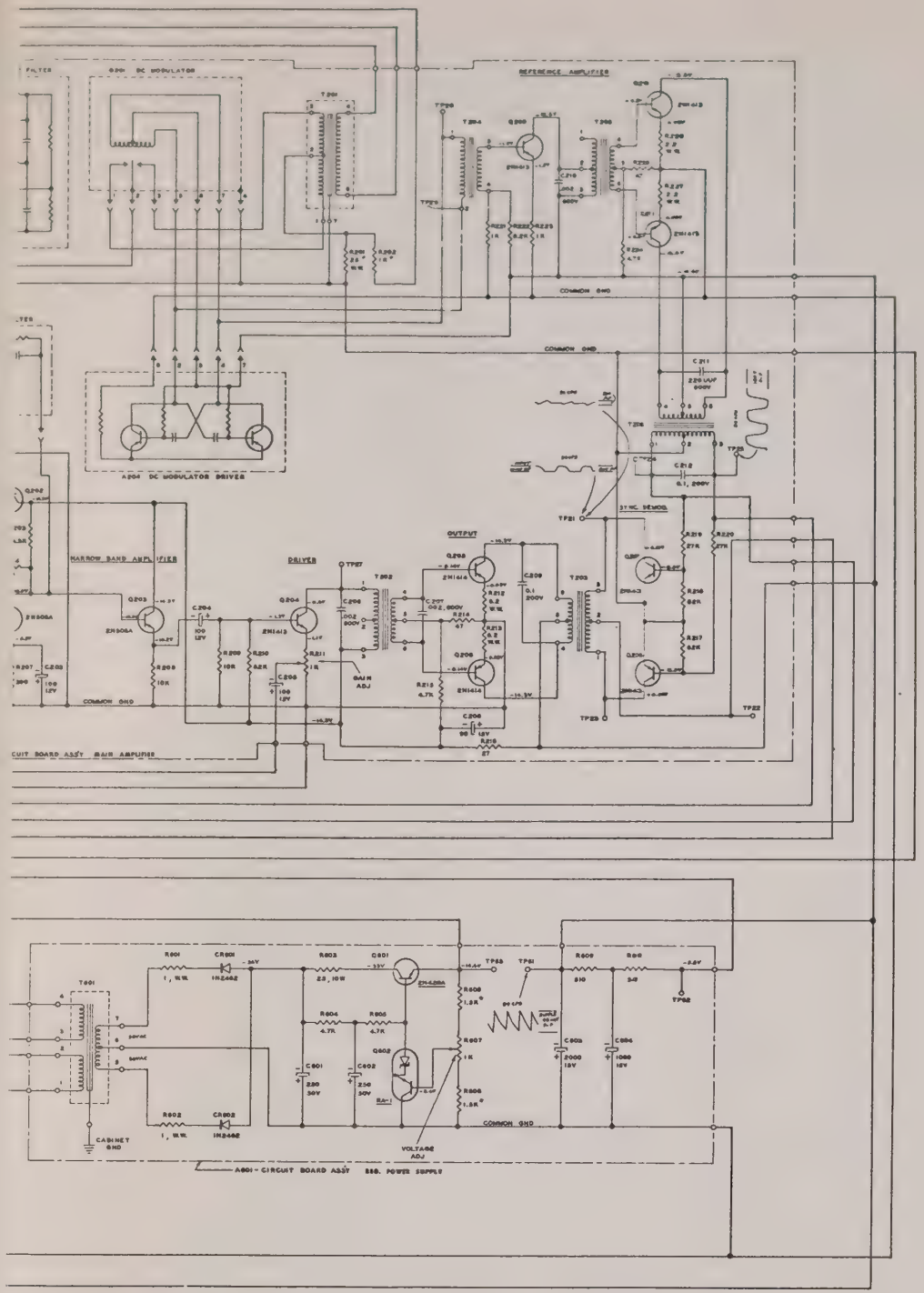

NOTES

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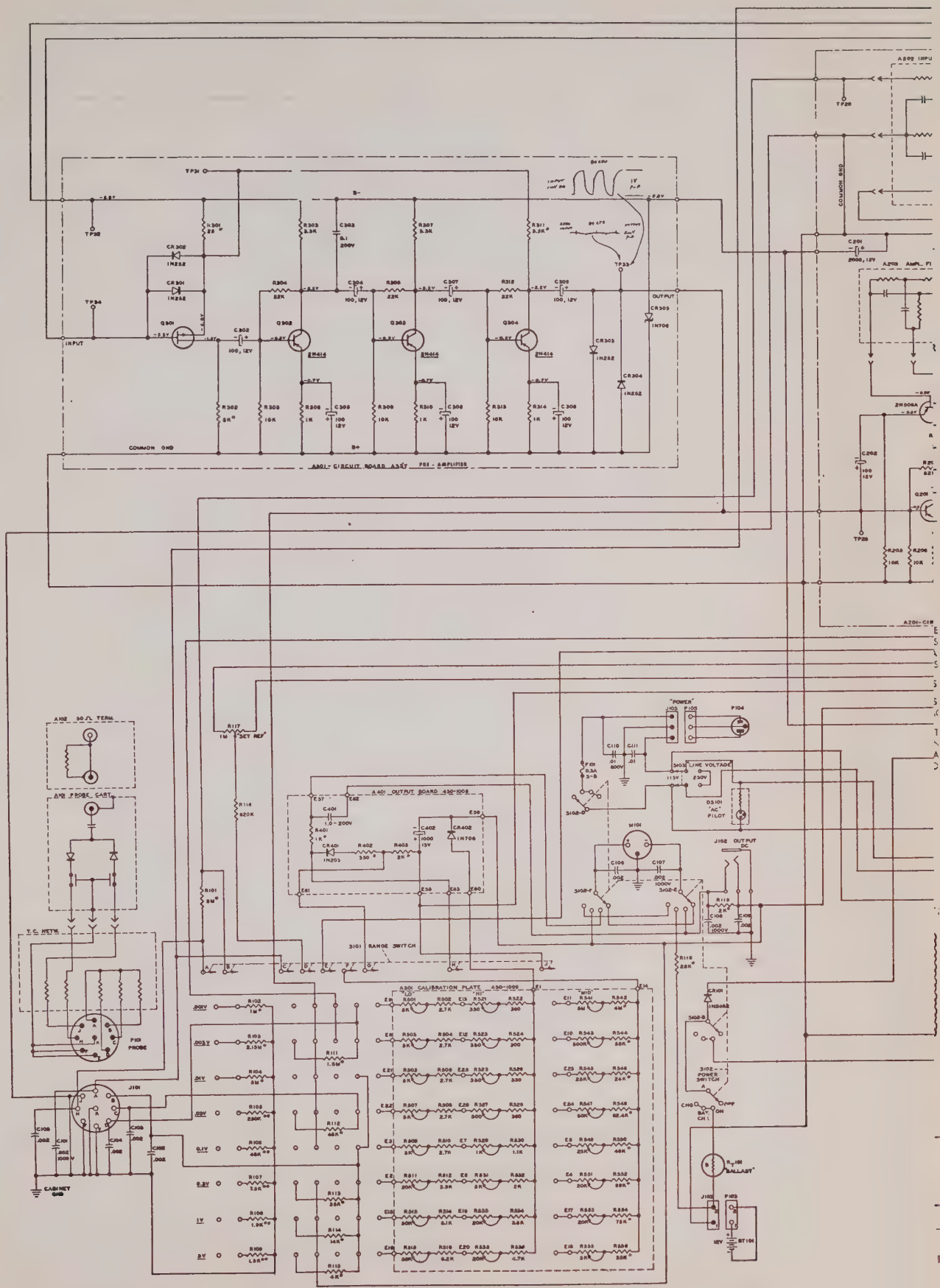
2. RESISTORS MARKED BY * ARE PRECISION TYPE ± 1%.
3. RESISTORS MARKED BY ** ARE SELECTED IN MANUFACTURE, AVERAGE VALUE SHOWN.
4. VOLTAGE MEASUREMENTS:
   LINE VOLTAGE INPUT 115V AC.
   MADE WITH RESPECT TO COMMON GROUND POINT.
   VOLTAGE VALUES INDICATED ARE ± 10%.

NAME: MILLIVAC INSTRUMENTS, INC.
SCHENECTADY, NEW YORK

TITLE: SCHEMATIC DIAGRAM OF MV-928A
RF MILLIVOLTMETER

DWG NO: 928A-1050 **DATE:** 6-11-65



Attenuator, Switching, Output, Meter and Interconnecting Circuits

GUARANTEE

Millivac Instruments, Inc. guarantees each instrument manufactured by us to be free from defects in material and workmanship for a period of one year from date of delivery to the original purchaser. Repairs during this time will be made by us free of charge, but transportation charges both ways will be borne by the customer.

Excluded from this guarantee are tube and transistor replacements, as well as all damages caused by, or related to, abuse of the instrument either electrically or mechanically. In this case, repairs will be billed at cost and an estimate will be submitted for your approval before the work is started.

If an instrument is believed to be defective, please notify our Service Department, giving the model number and serial number of the instrument, as well as describing the nature of the trouble. Our Service Department will then, if necessary, authorize the return of the instrument under the terms of this guarantee and advise how shipment should be made.

CLAIM FOR DAMAGE IN SHIPMENT

If, on receipt, the shipping cartons appear to be crushed or torn, as evidencing rough treatment, a notation should be made on the carrier's delivery receipt indicating this condition.

As each item is opened, it should be inspected to ascertain that no damage has been incurred during shipment. If no damage is visible, operational checks should be performed to make sure that the equipment arrives in its original operating condition. If any damage is revealed, a claim should be filed immediately with the carrier, stating the extent of the damage. A copy of this report should be forwarded to us along with the model and serial number of the instrument. Millivac will then advise how the instrument should be returned for repair or replacement.

SHIPPING INSTRUCTIONS FOR RETURNS TO FACTORY

No instrument should be returned to the factory without prior authorization from Millivac Instruments, Inc. or our authorized representative.

Shipping instructions will be given at the time return of an instrument is authorized. In all cases the instrument should be packed in a strong container and surrounded by sufficient shock-absorbing material.

NO: ME 4888 C.1

TITLE: OPERATING AND SERVICING MAN MANUAL

~~FURNEY PML 431 225~~

C.1
ME-4888